

Farmer Education Program (PEPA) Resource Guide

Pest, Disease and Weed Management Plan



Agriculture & Land-Based Training Association (ALBA)

May 2012

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This project was supported by the Beginning Farmer and Rancher Development Program of the USDA National Institute of Food and Agriculture, Grant #2009-49400-06025 and the **Outreach and Assistance for Socially Disadvantaged Farmers and Ranchers Program** of the USDA Office of Advocacy and Outreach, Grant #59-2501-10-001. Curriculum project support was also provided by the **Cedar Tree Foundation** and the **Organic Farming Research Foundation**.

Module: Pest, Disease and Weed Management Plan

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“Controlling pests and diseases organically means much more than simply changing the types of sprays and dusts you use. Organic gardeners strive to develop a balanced system where problems are regulated naturally and where there is little need to use even the safest organic sprays and dusts to control pest problems.” (1)

The Organic Gardener’s Handbook of Natural Insect and Disease Control
Ed. by Barbara W. Ellis and Fern Marshall Bradley

Many insects perform beneficial jobs such as pollinating crops, eating pests, and decomposing plant material. Entomologists estimate that more than 90% of all insects have a beneficial impact on crops (Ellis and Bradley, 256–258). For example, when an experienced farmer sees a Hover fly in the field, he or she knows not to be afraid since the Hover fly eats the aphids that plague crops.

Learning Objectives

1. Recognize, define and distinguish the organic and integrated pest management approaches to managing insects, diseases and weeds.
2. Identify and classify insect pests, disease pests, weed pests and vertebrate pests.
3. Describe and apply the six components of IPM for insect, disease, weed and vertebrate management: Prevention, pest identification, monitoring, tolerance levels and economic thresholds, control methods and evaluation.
4. Describe the life cycle of one of each type of pest: insect, disease, weed and vertebrate.

Introduction

Insects, diseases, weeds and vertebrates (from this point forward in this document we call these four in general, “pests”) can be serious challenges on a farm. They can damage crops, reduce crop yields and negatively impact crop quality. Conventional farmers use synthetic pesticides to combat pests. Besides being hazardous to farm workers’ health and leaving toxic residues on crops, the use of these pesticides have other negative consequences. Pests can develop resistance to pesticides, requiring an altered or stronger pesticide. Further, pesticides kill many beneficial insects and natural enemies, causing pests to multiply in greater numbers and crops that previously depended on insects for pollination fail to bear fruit.

Certified organic farmers must prevent and control pests without using synthetic pesticides. Organic farmers begin by trying to prevent a pest or disease outbreak from occurring in the first place. They may do this by maintaining healthy soil and vigorous crops, and by designing a diverse habitat for beneficial insects and natural pest enemies. They also use biological, mechanical and physical controls. Likewise, many cultural practices prevent the spread of pests. As a last resort, organic farmers may use an organic pesticide or disk in a crop to avoid a severe pest infestation. Even though the organic approach requires more thought and creativity than simply spraying to eradicate a problem, it has a lower environmental impact and can be cost-effective.

Much of what you have learned in previous chapters of this guide about soil fertility, crop planning, and irrigation is relevant to pest and disease control and prevention. Most decisions that farmers make regarding soil management, crop rotations, bed preparation and harvesting will impact their crops susceptibility to pests and disease. For instance, clay soils with poor drainage may make certain root diseases more probable, while harvesting can spread pest infestation if tools are not properly cleaned. Thus, pests and diseases cannot be approached in isolation from other aspects of farm management. Everything is connected in the farm ecosystem.

What is a pest?

An organism is considered a pest only when its activities start to damage crops and affect yields. Pests can be insects or other arthropods such as snails, mites and slugs. Pests are also disease causing agents such as fungi, bacteria, viruses and nematodes. On the farm, the word pest is also given to weeds, birds, rodents and other vertebrates.

Farmers are likely to encounter pests in the field, soil, and surrounding environment before, during and after crop production. Pest damage is a serious problem on the farm and requires the farmer's careful attention. A farmer should establish an effective system of pest prevention and control in order to minimize crop damage and sustain a successful business.

Integrated Pest Management

Effective pest management requires a multi-faceted approach and addresses the entire farm eco-system.

Integrated Pest Management is a management *strategy* that *combines a range of appropriate and complimentary techniques* with the goal of keeping pest populations at an *acceptable level* and *reducing or eliminating pesticide use*. A healthy and balanced ecosystem is the centerpiece of Integrated Pest Management. This approach can be cost-effective and environmentally sensitive.

While it may not be possible to completely eradicate pests, integrated pest management aims to prevent, lessen, and control pest populations and damage.

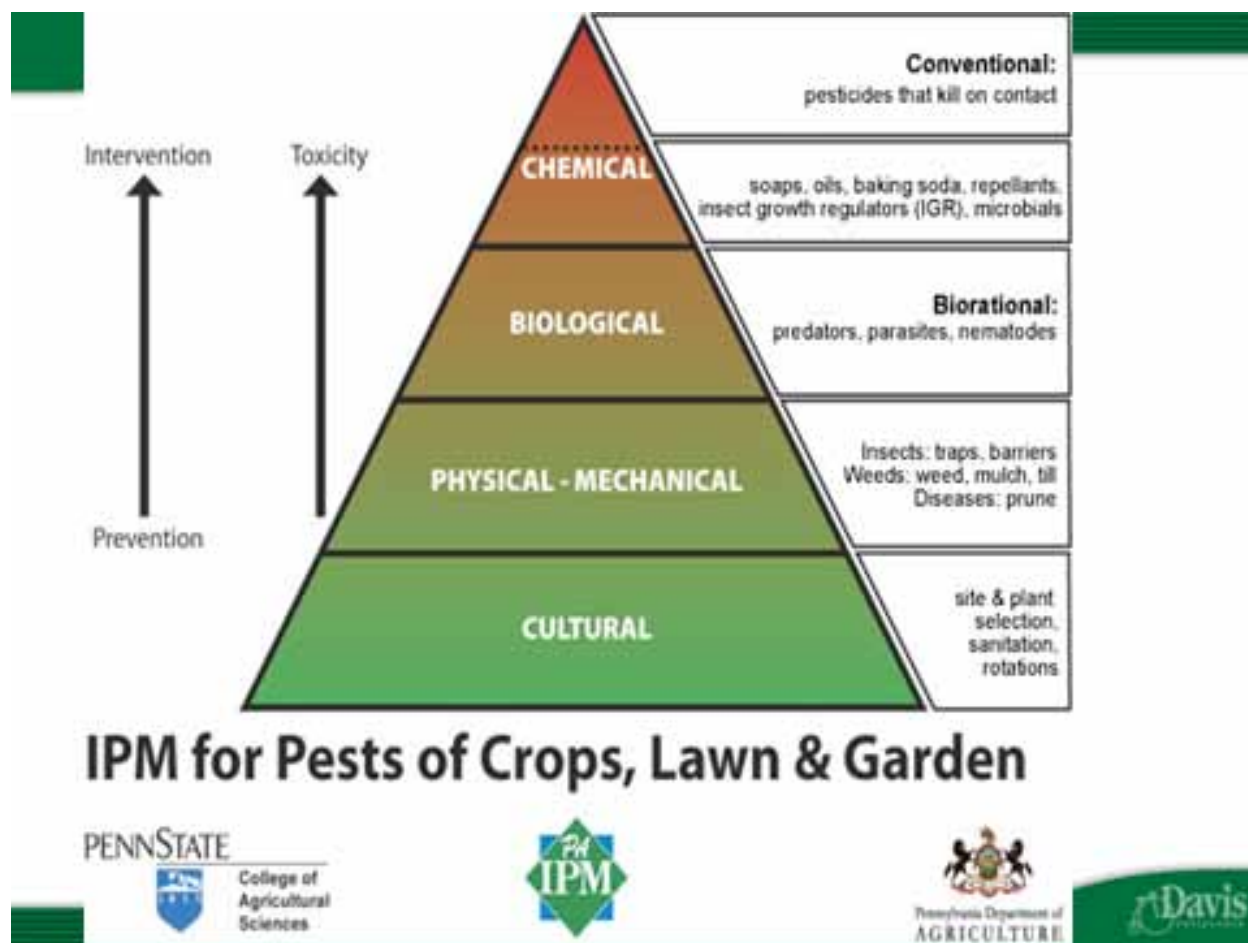
"Integrated pest management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties.

Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms, and the environment."

UC IPM Online.

<http://www.ipm.ucdavis.edu/IPMPROJECT/about.html>

Both conventional and organic farmers can benefit from IPM strategies. Some conventional farmers use Integrated Pest Management to address pest problems with the use of chemical, broad spectrum pesticide considered a "last resort" In a similar fashion, organic farmers are required to follow IPM-like practices using an organically approved input or pesticide only when other strategies with less of an environmental impact have been exhausted. See below for a diagram outlining IPM strategies, where prevention is the basis of control:



Integrated Pest Management (IPM) is a holistic strategy that encompasses prevention, pest identification, monitoring, tolerance levels and economic thresholds, control methods and evaluation. While specific prevention strategies and control methods must be tailored to each farm, IPM provides tools that help the farmer make smart pest management decisions.

Farmers can benefit by applying the following the **Six Components of IPM in the Field** for insects and arthropods:

1. **Prevention.** Smart management decisions can prevent susceptibility to pests.
2. **Pest Identification.** It is critical to correctly identify an organism in order to confirm that it is indeed a pest and plan for the best solutions.
3. **Monitoring.** By identifying pests and measuring infestation, farmers can make better decisions about when and how to apply a control method.
4. **Determining tolerance levels and economic thresholds.** Action must be taken when costs of pest damage exceed the costs of the control.
5. **Control Methods.** When possible, use the most effective (with the least negative impact) cultural, mechanical, biological, and/or natural chemical controls to manage pests.
6. **Evaluating the pest management strategy.** Evaluation allows one to identify how and why the management strategy was successful or not and to improve it when possible. This requires keeping records so that one can learn from his or her mistakes and successes!

Insect Pest Management – and general pest considerations

The following section focuses on the Six Components of Integrated Pest Management and how they apply to insect pests. In addition, a general explanation of the Six Components and how they apply to different types of pests is provided.

1. Prevention

The first step in constructing an IPM plan is to make sure you have thought about pest prevention and management considerations that are most appropriate for your situation—before you begin planting! The following considerations will help a farmer decide which preventative strategies will be most effective in their individual farming system:

Important Pest Prevention Questions to Consider:

A. What pest-resistant plant cultivars can be grown? There are many pest-resistant seeds and transplants a farmer can use that will help minimize pest damage in the field.

B. What cultural and habitat design will discourage pests and attract beneficial insects? Many farmers plant insectary plants or rows to attract beneficial insects as a pest control measure. Some insectary plants can also repel pests – another form of pest control.

“The cheapest and often most reliable way to avoid many pest problems is to provide an environment that discourages pest activities or reduces the plant’s susceptibility to damage.

These types of methods often include adjustments in cultural practices such as:

- Planting time
- Soil or bed preparation
- Water management
- Choice of crops or varieties
- Management of areas adjacent to the garden, farm, or orchard.”

(Flint (p. 9). *Pests of the Garden and Small Farm: A Grower’s Guide to Using Less Pesticide.*)

C. What crop rotations are needed to discourage pests? Timely crop rotations reduce the risks of disease or soil-borne pest problems. A good rule of thumb is to make sure to rotate different crop families in the same field each season. Potential host crops which attract pests should only be rotated at appropriate seasons and time intervals. For example, in some areas farmers are recommended to have a four-year gap between repeating brassica family crops in the same field.



A Farm is Not an Island: The diversity of ALBA's Triple M Ranch provides habitat for a variety of beneficial insects. Photo courtesy of Jo Ann Baumgartner

D. What is the quality of the soil and how does poor or optimal soil quality influence pest development and control?

Nutrient deficiency in a farmer's soil can predispose a field to pest development. In this case, practices such as cover cropping, green manures, and reduced tillage may improve soil quality. How will you manage field residue that can harbor pests?

Farming practices at ALBA recognize that the biodiversity of our land helps many farmers control pests. For instance, at ALBA's 110 acre ranch in Salinas, over 30 farmers grow over 50 different crops—including fruits, vegetables and flowers.

E. When and what type of pest monitoring will be used in the field?

You must decide the appropriate technique to scout for pests: sweeps, traps, nets, hand lens. Although observation is the best monitoring tool, certain pests will require specific monitoring techniques depending upon what part of the plant a pest attacks. Monitoring pests will help you determine the number of pests present, the stage of development, and the damage being done in order to analyze injury levels and treatment times. (Dufour, 2006)

At the Triple M Ranch, ALBA has established native plant hedgerows and trees at borders and between fields which attract beneficial insects. This diversity provides habitat and pollen for many carnivorous insects that eat the pests and control their populations.

- F. What type of record-keeping system will be needed to facilitate pest management decision-making?** Will you need field maps, background history of what was grown on the field in previous years? You will need to also record your pest management inputs each season, how will this be conducted? Keeping records will give lessons-learned and best management practices to consider in the future.
- G. What type of pest management equipment will be needed?** Mowers, cultivators, no-till drills, flamers, and beneficial organism application equipment are all examples of equipment that will be useful.
- H. What are the organic pesticides necessary and what are the best times for treatment in order to decrease pest populations while conserving beneficial insects?** The answer to this question very much depends on the specific pest issue. See I below. (Dufour, 2006)
- I. What IPM resources will be needed?** Will you need the services of a pest control advisor (PCA)? Locate your nearest County Extension Office and review the resources regarding pest management available.

Did you know that the University of California has a Statewide Integrated Pest Management website?

<http://www.ipm.ucdavis.edu/index.html>

Monterey County Extension Office:

<http://cemonterey.ucdavis.edu/>

Santa Cruz County Extension Office:

<http://cesantacruz.ucdavis.edu/>

San Benito County Extension Office:

<http://cesanbenito.ucdavis.edu/>

2. Pest Identification

When an insect, pathogen, or other pest is misidentified, the resulting control action may be ineffective. Many pests look similar to each other and similar to beneficial or harmless organisms. Furthermore, the organism that causes the damage may no longer be on the plant or may be hard to find. Other factor--such as poor fertility or irrigation management, toxins in the soil or water, air pollution, cold, heat, hail, wind, or genetic disorders—may also cause symptoms which appear similar to pest damage (Flint, p. 9).

To successfully identify pests, farmers can consider the following questions:

1. *Is the organism an insect or another type of arthropod?*
2. *What is the life cycle of an insect?*
3. *How is the organism classified?*

1) *Is the organism an insect or another type of arthropod?*

In order to identify an insect pest, a farmer must first determine if the pest is an insect or another type of arthropod.

Arthropods are a group classification assigned to organisms in the animal kingdom under *Phylum Arthropoda*.

Arthropods have segmented bodies and hollow jointed legs and are made up of insects, spiders, snails, mites, slugs and crustaceans.

Insects have:

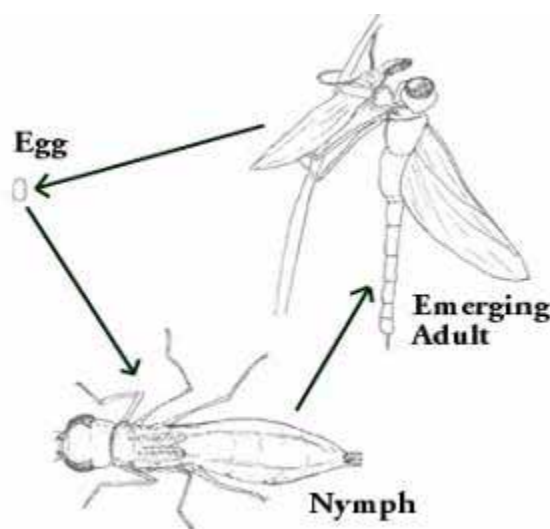
- 6 legs
- 1 pair of antennae
- Many insects have wings, but not all.
- 3 separate regions of the body :
 - The **head** contain the eyes, the antennae and mouthparts.
 - The **thorax** is in the center of the body and contains the legs and wings.
 - The **abdomen** is at the end of the body and contains digestion, respiration, and the reproductive organs.

Other arthropods such as mites, spiders, slugs, and snails are not considered insects because they do not have the exact characteristics mentioned above. However these arthropods can be considered pests since they have the potential to reduce crop yields on the farm.

2) What is the life cycle of an insect?

Insects can go through one to several life cycles or stages of development in their lives. Often these stages correspond to varying times of crop development causing a tremendous amount of crop damage at specific times of the growing season. For example, an adult cucumber beetle can feed heavily on potatoes at the middle and late stages of crop development. Some insects go through developmental stages that create more crop damage than other stages. For example, the larval or immature stage of development of a beetle can create more crop damage than the adult stage in some cases.

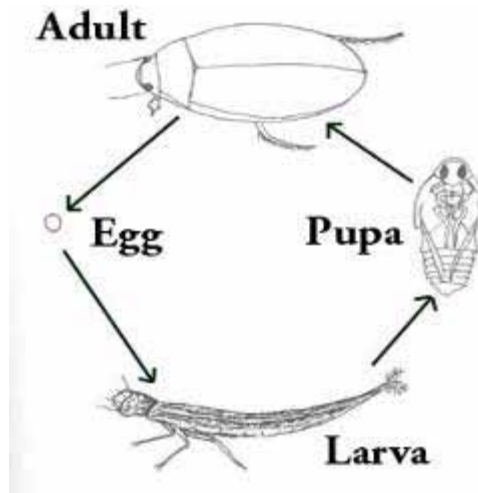
Insect metamorphosis — Insects go through a series of changes or stages of development from egg to adult called metamorphosis. There are 2 distinct forms of metamorphosis: *incomplete* (also called simple) and *complete metamorphosis*.



Insects that go through **incomplete metamorphosis (Fig.1)** are characterized by the following stages: egg, larva (immature, also called nymph), and adult. These insects do not go through major changes. The young either resemble wingless adults (e.g. Hemiptera) or are only slightly different from their adult stage (e.g. Odonota). Aquatic nymphs are sometimes called naiads.

Figure 1. Incomplete Metamorphosis
(University of Michigan Environmental Interpretive Center)
<http://www.umd.umich.edu/eic/>

Insects that go through **complete metamorphosis (Fig.2)** are characterized by the following stages: egg, larva (immature), pupa, and adult. The larva form is very different from the adult form. Maggots (flies), caterpillars (moths and butterflies), and grubs (beetles) are examples of the common names of some insect larvae.



*Figure 2. Complete Metamorphosis
(University of Michigan–Environmental Interpretive Center)*

3) How is the pest classified?

Pests can be classified by their Order, their behavior, or by the type of mouthparts they have. Each is discussed below.

a) Classification of insects by *Order*

When trying to identify an unknown insect you can try to determine its correct *Order*. This can be done with the help of an identification guide or key. See **Appendix A** for a complete list of insect orders.

b) Classification of insects by *Behavior*

Farmers may also classify insects depending on their behavior on the farm. Some insects impact crops negatively, some positively, and others may be present but have neither positive nor negative effects. It is important to note that most insect species are *not* pests.

Insect Pests – Negative Behavior

An organism is a pest only when it has a negative impact on the crops. Remember, the definition of a “pest” is an organism that begins to damage crops and affect and reduce yields.

Beneficial Insects – Positive Behavior

There are some insects that are natural enemies of pests and beneficial to the farmer. These beneficial insects feed on insect pests, thus controlling pest populations. For example, the Assassin Bug kills caterpillars and Ladybird Beetles control aphid populations. Bees are beneficial because they pollinate crops and also produce honey.

Neutral insects – Neither negative nor positive behavior

If the insect or arthropod is not a pest and not beneficial than we can call it neutral because its behavior does not damage the crops or affect yields. For example, a house fly can be considered a neutral insect because it neither harms the crop nor protects the crop from other pests.

c) Classification of insects by *Mouthparts*

Farmers can also identify a pest by its mouthpart and the damage these mouthparts cause. Arthropods have a wide variety of mouthparts. Some mouthparts allow insects to chew plants/ roots and other mouthparts are used for probing and sucking. Being able to distinguish the mouthpart and the type of damage it causes will help you identify the insect causing the damage.

There are two main categories of mouthparts: *Chewing mouthparts* and *Non-chewing mouthparts*.

Chewing mouthparts

Chewing mouthparts are the most primitive type and are often referred to as “mandibulate” mouthparts. The type of chewing mouthparts a pest has depends on the type of food it feed on. Typically, these mouthparts result in parts of the plant showing holes in the leaves or chewed edges. Although the chewing mouthparts may differ, **Figure 3** shows the basic structure of chewing mouthparts.

Familiar insects with chewing mouthparts are grasshoppers, beetles, and various caterpillars.

Non-chewing mouthparts

Non-chewing mouthparts are modifications of chewing mouthparts and are used to suck liquids or rasp across the surface of the leaf.

Piercing-sucking mouthparts

Piercing and sucking mouthparts are elongated to form a proboscis for piercing plant tissues. A well known insect with a proboscis is the mosquito. **Figure 4** shows an insect (Family: Miridae, Order: Hemiptera) with a long proboscis stemming from its mouth. The insect pierces the surface of the plant with its proboscis and sucks out the sap inside to remove the green chlorophyll from the plant. This causes the affected area to become brown and wilt or develop a tumor-like growth. Examples of insects with piercing-sucking mouthparts include; aphids, leafhoppers, mealy bugs and fleas.

Rasping-sucking mouthparts

Rasping and sucking occurs when the insect or other arthropods scrapes off the leaf surface and sucks up the fluids from the top layer of plant cells. Examples of pests with rasping-sucking mouthparts include thrips and mites. These pests remove the top layer of cells and suck out the cell contents, causing the leaf to look a silvery or bronze color.



Figure 3. Chewing Mouthparts



Figure 4. Proboscis of a mirid

3. Monitoring

Monitoring (or scouting) pests helps to *identify* and *measure* pest infestations and crop yield loss.

Measurement of pest infestation

Farmers need to measure pest infestation in order to know how the pest will influence yield, when to apply controls, and what type of control methods are appropriate. This can be difficult since yield loss can be influenced by not only pest severity, but also by other factors like fertility and weather. Therefore, in order to best understand how pests will potentially influence yield, the farmer will need to measure pest infestation in three ways:

- 1. Numbers of the pest present**—Estimates on insect numbers or density are usually made through field sampling by visual observation and rating via actual counts of the insect on the crop, or by measuring the proportion of those plants or plant parts that are infested.
- 2. Pest developmental stage**—The development stages of a pest vary from an egg, immature stages to an adult depending on the type of pest being measured. When the pest is in a certain developmental stage some pests are more harmful than others. Therefore, understanding which stage does the most harm prepares farmers for control methods during these periods.
- 3. Duration of the pest attack**—The length of time for which a pest infestation is present on a plant or crop will also influence the extent of yield loss.

The combination of these three factors in relation to the crop influences crop yield with regard to pest.

Identifying crop yield loss

Insect and other arthropod pests have the ability to reduce crop yield. **Yield** is the amount of useful and profitable product obtained from a crop after the growing season. A farmer can experience yield loss as a reduction in crop vigor, size, and/or visual aesthetics. Such factors can make the crop unmarketable. Monitoring for pest infestation helps to estimate crop yield loss. There are four general types of insect damage which contribute to yield loss:

Indirect Damage — Pest feeds on non-marketable portion of plant, causing yield loss.
(i.e. aphids on stems and leaves, root and seed maggot)

Direct Damage — Pest feeds on marketable portion of plant, causing primarily quality loss.
(i.e. earworm in sweet corn ears, cabbage worms)

Damage by Vector Diseases — Insect transmits organism that causes plant disease, causing yield and quality losses. (i.e. cucumber beetles/bacterial wilt, flea beetles/Stewart's wilt)

Damage caused by Contamination — Presence of insects, insect parts, or insect products makes the product less marketable, and therefore less valuable, or completely unmarketable.
(i.e. heads of cauliflower covered in aphids)

Exercise: Call or talk to an experienced farmer and ask him/her if you can monitor one crop that has pests in his/her field. Ideally, he or she can be present with you in the field as you attempt to answer the following:

What is the crop you are investigating?

Examine ten plants randomly in one row. Count the number of pest you see on these ten plants.

What pests did you find?

What developmental stage are the pests in?

How long has the farmer seen these pests on his/her crops?

What control methods does the farmer use for these pests?

Types of Monitoring

Field Observation can be useful to determine pests and beneficial insect populations. Plant diseases, environmental disorders, and improper cultural practices can also be observed visually. Field observations should be done by the same person throughout the season. That means regularly checking plants in a number of different areas of your farm. One good way to do this is to follow a zigzag pattern each time you do a visual inspection. Randomly choose plants to inspect along the way. Begin inspection at the bottom of the plant and proceed upwards, from older leaves to younger leaves to new growth. Special attention should be paid to buds and blooms. Be sure to mark affected plants for easy identification on your next visit so you can evaluate any changes that may occur.

Magnification — To properly observe pests, it is helpful to use a hand lens. Hold the lens close to your eye and move the object you are looking at until you have it in focus. Magnification is expressed as “x.” A 20x magnifier shows you an object 20 times larger than life, so be sure to choose the lowest magnification needed for your task. The lower the magnification, the greater the “depth of field” and “field of view.” For example, at 2x you may be able to see an entire insect clearly, from the tips of its antennae down to its tarsi (toes). At 10x, you will see either antennae or tarsi in greater detail, but not both at the same time.

What to look for during field observation:

- *The presence of plant diseases or insect pests* — Try to determine the species of the pest, what stage it is in? How many insects are present? How are the pests distributed (i.e. evenly distributed, scattered or localized)? **Note:** Some insect pests are very mobile, and it will be difficult for you to count how many are on a specific plant. In these cases, use of a sweep net or insect trap can help you (Sweep netting is discussed in the next section).
- *Symptoms or damage to the plant* — Look at the plant's characteristics. How do they differ from the appearance of a normal plant? What is the severity of damage? Where on the plant is the symptom or damage found? How many nearby plants appear to be affected? Also try to determine the cause of the symptoms if it isn't readily apparent.
- *Other insects* — In the case of an insect infestation note whether any beneficial insects are present (natural enemies of the pest). Also note the presence, numbers and distribution of any other insect pests that could cause additional problems.
- *Weather conditions* — Note the current conditions (temperature, precipitation/soil moisture, wind speed) and whether there are any obvious variations from otherwise normal conditions at that particular time of year. It's also important to look back and note weather conditions from the past week or so to determine whether any unusual weather events occurred.
- *Other contributing factors* — Note when pesticides were last applied to the plant, and when other practices such as fertilization or irrigation took place.

Examples of pests that are visible during field observations: Colorado potato beetle; potato, cabbage, and turnip aphids; European corn borer; seed corn maggot; corn rootworm beetles; spider mites; leaf hoppers, cole crop caterpillars; thrips; flea beetles; leafminers; cucumber beetles; and the squash vine borer.

Trapping

Pheromone traps are easy to use and are pest specific. A lure usually contains a chemical attractant placed inside or on the trap, depending on the trap design. This lure emits a sex pheromone produced by the female pest species of interest. This lures male insects to the trap. Keep in mind that pheromone traps may provide misleading information when a farmer has only a few furrows of a crop he or she believes is infested with a particular pest; the traps may draw in pests from outside the target area (Flint, p. 9).



Pheromone traps (**Figure 5**) are used to monitor the following insects: Lepidopterous insects (butterflies and moths) of which the juvenile stage, caterpillars, are vegetable pests. Armyworms, cutworms, and the corn earworm are commonly monitored with pheromone traps.

Figure 5. Pheromone Traps (Jack Kelly Clark, 2000).

Sticky and dishpan traps — Farmers can also use sticky traps and dishpan traps for effective pest monitoring and control in some cases. Sticky traps (**Figure 6**) are yellow rectangular paper mounted on a wooden stake with adhesive glue placed over the entire surface on both sides. The sticky traps are then placed in regular intervals along crop rows. Pests will be attracted to the yellow paper and get trapped on the glue.



Figure 6. Sticky traps

For dishpan traps, fill a yellow dishpan with soapy water. Adult flies, certain maggots, and aphids will be attracted to the traps, fall in and die. Place the traps at 100 foot intervals along the field edges and check them every 3–4 days. Replace the soapy water as needed.

The University of California IPM online website identifies crop-specific pest management guidelines at this website: <http://www.ipm.ucdavis.edu/PMG/crops-agriculture.html>

Sweep Net Sampling



*Figure 7. Scouting with a sweep net
(Source: IPM Program at Iowa State University)*

Small insects are best monitored with a sweep net, particularly if there is a large area to cover. From a practical standpoint, sweep net sampling works best on low-growing crops like carrots, peas, and leafy greens. Sweep nets (**Figure 7**) are available in muslin or sailcloth. Choose a muslin sweep net for scouting vegetables since it is lighter, more flexible and will dry more quickly. Insects such as aster and potato leafhopper adults, flea beetles, tarnished plant bugs and pea aphids are easily monitored with a sweep net.

To effectively use a sweep net, swing the net in an arc in front of your body as you walk through the field. One “sweep” is considered going from right to left and back again in a 180° arc. Take 5 sweeps, quickly pulling the net through the air to force all insects into the bottom of the net bag. Grasp the net bag with your hand about at the mid-point to capture the insects in the bag.

Slowly invert the net bag while releasing your grasp on the bag allowing the insects to escape and count the numbers of key species. To get an accurate representation of insect numbers, collect samples from all portions of the field but avoid unusual parts of the field, such as field edges. One exception to this is when sampling leafhoppers, which tend to be concentrated initially on the field margins.

Many slow-moving insects, such as weevil larvae, aphids, and caterpillars can be counted by turning the net onto a white pan or other flat surface. Divide totals by 5 to get the average number of insects per sweep.

Steps in Monitoring

In order to effectively monitor pests, a farmer must be assigned and trained to scout vegetables and fruit crops. The following steps are used in monitoring:

- Record type of plant being monitored, its size, location, condition, and date and time inspection took place.
- Monitor the crops for insects (using methods described above) on a regular or weekly basis, and note number of pests, their stage of growth, and distribution.
- Identify any beneficial insects
- Take representative plant samples in the field
- Assess the growth status and general health of the crop
- Record the findings on field data sheets

Monitoring pests effectively will save you money, make your pest control plan more effective, help to understand the pest life cycles, and help preserve the beneficial organisms on your farm. This information forms a sound basis for decision making.

4. Determining tolerance levels and economic thresholds

Even after doing everything possible to prevent pest infestation, all farmers make decisions about when to tolerate a pest and when to take stronger action to control it. The **Economic Threshold Level** for a specific crop helps a farmer determine at what level of infestation a pest is considered an economic problem. Farmers will have to decide when suppression measures

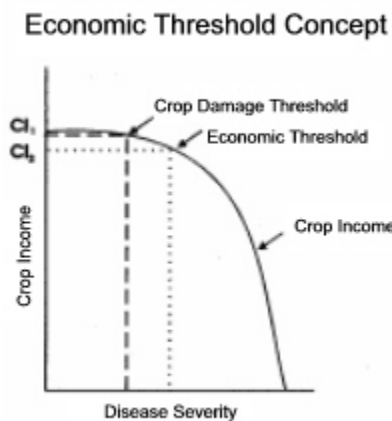


Figure 8. Economic Threshold Concept

should be implemented in order to prevent the pest population from reaching the **Economic Injury Level** — the amount of pest infestation on a specific crop when damage is above the economic threshold level and the cost associated with that damage is equal to or exceeds the cost of control.

Economic thresholds level is the maximum level of disease or pest infestation at which control action should be taken to prevent further spread of the disease and yield loss. **Figure 8** is a simplified economic threshold. Crop income (solid line) quickly decreases as the plant disease severity and damage increases.

One way of understanding economic thresholds is to start with the *cost of control*.

1. Estimate what the cost will be to apply a pest management control.
2. Estimate the amount of yield you would lose if the control measure was not taken.
3. If the amount of yield loss costs more than the control measure taken, then it would be worthwhile to spend money and implement the control measure.

Pest infestation values for economic threshold levels are determined through monitoring and are different for specific crops and specific pests. Density of pests may be represented as pests per square foot; insects per leaf, adults per trap; adults per plant; insects per linear feet, etc.

Typically a destructive insect feeding on a high valued crop results in a low economic threshold level. A low valued crop combined with a less destructive insect result in a higher economic threshold level.

“Fundamental to integrated pest management is the concept that a certain number of pest individuals or a certain amount of pest damage can be tolerated. The difficulty is in determining the point at which some action must be taken to control the pests to prevent unacceptable damage. For some pests in some crops, researchers have developed control action guidelines that indicate when management actions (usually a pesticide application) must be taken to avoid economic loss... Control action guidelines are helpful only when used with accurate pest identification and careful field monitoring.” (Flint, pp. 10-11)

Table 1. Examples of Economic Threshold Levels,
(Adapted from Practical IPM-Brad Lewis, 2002)

CROP	PEST	THRESHOLD LEVEL	NOTES
Chilis	Pepper Weevil	Multiple individuals caught in pheromone trap	Economic threshold level is variety dependent; imported pest, multiple generations per year
Onions	Thrips sp.	3–5/leaf	Individual plant samples, multiple generations per year
Corn	Southwestern Corn borer	20% egg or larvae infested plants	Individual plant samples, two generations per year
Corn	Western Corn Rootworm Adults	5–7 adults per plant prior to brown silk	Individual plant samples, larvae controlled with at-planting insecticides, one generation per year
Corn	Western corn rootworm larvae	2 nd year in corn and presence of adults the previous year	Larvae controlled with at-planting insecticides, one generation per year
Green Beans	European corn borer	Any present in the field	Sweep net samples after pod formation
Lettuce	Corn earworm	Less than 1% infested plant	Individual plant samples
Lettuce	Cabbage loopers and beet army-worms	Less than 5% infested plants	Individual plant samples

5. Control Methods

When possible, use cultural, mechanical, biological, and/or natural chemical controls with the least environmental impact to manage pests.

Cultural Control — is the deliberate alteration of the production system—either the cropping system itself or specific crop production practices—to reduce pest populations or avoid pest injury to crops. Cultural controls can:

- Prevent pest from multiplying on the crop,
- Create a reaction of adverse biotic conditions that kill individuals or reduce populations of the pest,
- Modify the crop to reduce damage, and
- Enhance natural enemies by manipulating the environment.

Types of Cultural Control

- **Selecting plant resistant varieties**
- **Crop rotation**
- **Cultivation, tillage practices**
- **Variation of planting or harvesting dates**
- **Plant spacing**
- **Fertilization level** (Example: It is often noted by experienced farmers that insects are attracted to weak, undernourished plants. Also, a well fertilized plant will grow and harvest more quickly, thereby decreasing likelihood of insect pest damage)
- **Sanitation** (Example: Cleaning storage areas and field residue helps prevent infestations of stored insect pests.)
- **Planting trap crops** (Example: A trap crop consists of a field margin planted to an early maturing crop that surrounds the main crop — or a plant that is more attractive to the pest than your own production. One example is intercropping alfalfa in strawberries. Lygus bugs, a formidable pest in strawberries, are highly attracted to alfalfa. The alfalfa can then be periodically vacuumed to remove the Lygus bugs)

Mechanical Control and *Physical Control* methods involve using barriers, traps, or physical removal to prevent or reduce pest problems. The idea with the use of mechanical control is to block the pest from its food source (the crop).

Types of Mechanical Control:

- **Hand picking and squashing** — In some cases it may be possible to pick pests directly off the crops. This can be done especially with caterpillars and other large insects in small plots of land. Smaller pests such as aphids can sometimes be washed off the plant with forceful overhead irrigation.
- **Exclusion** using screens or barriers (Examples: Floating row cover over young crops. Banding trees with Tanglefoot to control cankerworms.)
- **Trapping, suction devices, collecting machines** (Examples: Bug vacuum in large-scale organic strawberry production; walk-through fly trap removes horn flies from range cattle; apple maggot trap in orchard.)

Biological Control is the reduction of pest populations by natural enemies or biological control agents and typically involves an active human role. Farmers can implement biological control by attracting beneficial organisms or by purchasing them. Natural enemies of insect pests include predators, parasitoids, weed feeders and pathogens.

The University of California State-Wide IPM has a site called the Natural Enemies Gallery. This site is a great resource to help identify natural predators and parasitoids of common pests. <http://www.ipm.ucdavis.edu/PMG/NE/?printpage>

It is also available in hardcopy:
Natural Enemies Handbook: The Illustrated Guide to Biological Pest Control
Publication 3386 — Published 1998

Telephone ANR Communication Services at 1-800-994-8849 or (510) 642-2431.

Parasitoids are the larva of insect parasites. The insect parasites lay their eggs inside a host, which is the crop pest. As the larval develop, they feed on or inside of the host insect, eventually killing it. When the larva emerge from their host as adults, they will lay their eggs in other hosts, continuing the cycle. Wasps and fly larva, for example, are parasitoids that live on common pests.

Predators consume insect pests.

Lady beetles are well-known examples of predatory insects of aphids, mites, scales, mealybugs, whiteflies, small caterpillars, beetle grubs, and all types of insect eggs. Most people do not realize that these beetles come in many colors including red, brown, or black, and often lack spots. They are always looking for food. Larvae are more difficult to recognize. The larval stage is elongate and flattened, and usually blackish or bluish with orange spots. The eggs are yellow and deposited on end in clusters.

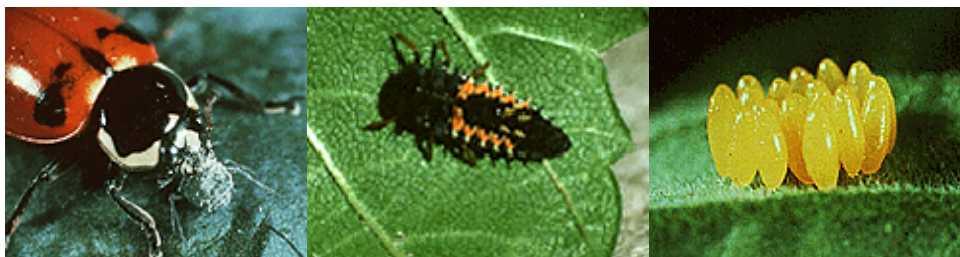


Figure 9. Lady Beetles Left: Adult Hippodamia parenthesis feeding on a cabbage aphid. J.Ogrodnick Center: Fully grown larva of Harmonia axyridis. A.T.Eaton Right: Lady beetle eggs. (John Kelly Clark, UC IPM 2000)



Figure 10. Mexican Bean Beetle (National Gardening Association, 2010)

BEWARE of the Mexican bean beetle (Fig. 10), which looks like a lady beetle but has a bronze color. It feeds on the leaves of your crops and *not* on other pests.

Lacewings Both green and brown lacewings adults are quite recognizable. Like lady beetles, lacewings are often found feeding on aphid colonies. However, unlike lady beetles, lacewings are beneficial in the larva stage; the adults do not always feed on insects. The large sickle-shaped mouthparts apparent in the larval stage are very effective for clamping onto prey and draining their body contents. The eggs of lacewings are placed on long thin stalks, and placed in clusters. Lacewings feed on insect eggs, scales, mealybugs, and mites as well as aphids.



Figure 11. Green lacewing adult, Chrysoperla carnea. (John Kelly Clark, IC IPM 2000)



*Figure 12. Big-eyed Bug Adult.
(Jack Kelly Clark, UC IPM 2000)*

Big-Eyed Bugs have oversized eyes in both the adult and immature stage. Besides their names-trait, they are fairly nondescript, small, grayish insects. The piercing-sucking mouthparts are used to drain the fluids from moth eggs, caterpillars, thrips, and mites.



*Figure 13. Minute Pirate Bug
(Anthocoris nemoralis) feeding
on a nymph. (Jack Kelly Clark,
UC IPM 2000)*

Minute Pirate Bugs Adults are silvery-white and black in color. Like Big-eyed Bugs, they feed on many small organisms by draining body fluids with their piercing-sucking mouthparts. They attack leafhoppers, aphids, thrips, and mites.

Soldier Bugs or Stink Bugs Many stink bugs are pests because they attack blossoms and fruit, causing deformity and fruit drop. But Spined Soldier Bugs are beneficial. How can you distinguish between good and bad stink bugs? All stink bugs have long, thin, tubular piercing-sucking mouthparts. The good bugs use their mouthparts to extract fluid from other insects, especially caterpillars and beetle grubs. The bad bugs use their mouthparts to extract plant sap. The mouthparts of good soldier bugs are relatively sturdy, whereas the mouthparts of pest species are relatively thin and frail. Remember to observe the bug's behavior before deciding whether it is good or bad.

Ants Farmers who have fire ant problems rarely have problems with caterpillars and other soft-bodied pests! Ants are not entirely beneficial, however, and in addition to their tendency to bite or sting, ants sometimes protect honeydew-producing insects such as aphids and scales from predation and parasitism. So ants are a mixed blessing, depending on the type of plants and pests present.

Syrphid flies Also known as hover flies for their ability to hover in flight, syrphid flies are common predators of aphids and other soft-bodied insects. Adults often look like bees (**Fig. 14**). Various stages overwinter, depending on the species, giving rise to adults in spring. Adults feed on pollen, nectar and aphid honeydew. Females must feed on pollen for proper egg maturation. Syrphid larvae pierce aphids with their piercing and sucking mouthparts, sucking fluids from the bodies before moving to other prey. Each larva may consume hundreds of aphids during its development.



*Figure 14. Adult Syrphid Fly.
(Jack Kelly Clark, UC IPM 2000).*

Predatory Mites Spider mites are known as serious plant pests, however some mites are beneficial. The phytoseiid mites are especially important because they are predators of plant-feeding mites and other small organisms such as thrips or insect eggs. Predatory mites tend to be larger than other mites, long-legged, and move actively in their search for prey. Predatory mites are particularly popular among organic strawberry growers.

Where to purchase biological control agents

There are many commercial sources of biological control agents or natural enemies. Quality varies among producers, so the farmer should consider suppliers who have been in business for at least several years.

A comprehensive list of suppliers is found at a California Department of Food and Agriculture web site on biological control: <http://www.cdpr.ca.gov/docs/ipminov/bensuppl.htm>

Exercise: Review the list of predators or natural enemies and photos on the UC IPM website link below:

<http://www.ipm.ucdavis.edu/PMG/NE/>

Organic Options for Chemical Control

Many pesticides used in conventional farming are made up of organophosphates, which are unhealthy for people and the environment. Diazinon, Malathion, Dursban (Chlorpyrifos) and Carbaryl are linked to permanent neurological and kidney problems, reproductive toxicity and death. (US News and World Report, 9/14/02) These pesticides work by inhibiting nerve and muscle response and were originally developed for use in chemical warfare.

On the other hand, many organic insecticides effectively control pests. They are derived from natural sources: e.g., Pyrethrum (pyrethins), Rotenone or Ryania from plants; or minerals, such as Boric Acid, Cryolite, or Diatomaceous Earth; or naturally occurring bacteria like Spinosads.

Note, although derived from natural sources and generally less harmful than chemical pesticides, some organic pesticides can be toxic to human and environmental health.

To determine the relative toxicity of any pesticide to humans, check the signal word stated on the pesticide label:

“CAUTION” — least toxic products i.e., slightly hazardous by any route of entry

“WARNING” — more toxic i.e., moderately hazardous by at least one route of entry

“DANGER” — most toxic i.e., highly toxic by at least one route of entry

Figure 15. Sample Pesticide Label

<p style="text-align: center;">Pyganic Organic Insecticide ECOTOXIC</p> <p style="text-align: center;">Registered pursuant to the ACVM Act 1997, No. P7039</p> <p style="text-align: center;">See www.nzfsa.govt.nz/acvm for registration conditions.</p> <p style="text-align: center;">Net Contents: 3.78 litres</p> <p style="text-align: center;">READ LABEL COMPLETELY BEFORE USING</p> <p>WARNING: This material may be harmful if swallowed. This material may cause skin and eye irritation and an allergic reaction in sensitive individuals.</p> <p>PRECAUTIONS: Keep out of reach of children. Store in original container, tightly closed, in a cool dry place away from foodstuffs, heat or open flame. Avoid contact with skin and eyes and inhalation of spray mist. When mixing or applying wear protective clothing, including face shield, impervious gloves and footwear. If clothing becomes contaminated with product, remove clothing immediately. Do not eat, drink or smoke while using. Wash hands and exposed skin thoroughly with soap and water before meals and after work. Wash protective clothing daily after work.</p> <p>Very toxic to bees and other terrestrial invertebrates. Spray must not contact plants in flower while bees are present.</p> <p>Very toxic to fish and other aquatic organisms.</p> <p>Container disposal: Triple rinse container and add residue to spray tank. Puncture and bury in a suitable landfill. Avoid contamination of any water supply with chemical or empty container.</p>

Taking a look at **Figure 15**, you can see that even though the insecticide, Pyganic, is organic, it is very toxic to fish, bees, terrestrial invertebrates and aquatic organisms. Therefore, it is important to realize that although some organic pesticides may be nontoxic or are only slightly toxic to people, they may also be extremely toxic to other animals

Did you know that amphibians (frogs/salamanders) are bio-indicators?

In other words, amphibians are indicators of a healthy or unhealthy environment. Unlike other animals, amphibians do not have lungs. Instead, they breathe through their skin. Amphibians live in both aquatic and terrestrial habitats; therefore, their health and population abundance is directly linked to water and air quality. With contaminated water or air, amphibians cannot breathe well through their skin. Low water levels do not give enough time to allow amphibian eggs and larvae to develop properly. As adults, the amphibians live on land and absorb air contaminants through their skin as well.

ALBA's Triple M Ranch is home to three important and endangered amphibian species (the California Red-Legged Frog, the Santa Cruz Long-Toed Salamander, and the California Tiger Salamander). A wetlands restoration project will be implemented on the Triple M Ranch to clean the water and to prolong the duration of water in the ponds to help the survival of these species. The Triple M Ranch farmers realize that an abundance of these amphibians on the ranch signifies a healthy environment and are working hard to ensure the conservation of these species on the ranch as they promote their own livelihoods.

Please note that as a California farmer it is necessary to have an Operator ID number on file with the County Agricultural Commissioner before applying any pesticide with an EPA number. Monthly Pesticide Use Reports (PURs) also need to be submitted.

The Organic Materials Review Institute

The Organic Foods Production Act of 1990 required the Secretary of Agriculture to establish an organic certification program for producers and handlers of organic products. Therefore, the National Organic Program (NOP) was developed to streamline the marketing of organic foods within the United States by developing, implementing, and administering national production, handling, and labeling standards for organic agricultural products. It also accredits the certifying agents (foreign and domestic) who inspect organic production and handling operations to certify that they meet USDA standards. The NOP put forth a National List of Allowed and Prohibited Substances which identifies synthetic substances that may be used, and the non-synthetic substances that cannot be used, in organic production and handling operations.

The Organic Materials Review Institute (OMRI) is a national nonprofit organization that determines which inputs or products are allowed for use in organic production and processing. OMRI constantly reviews products to add to the National List of Allowed and Prohibited Substances. Approved products on the OMRI List may be used on farms that are certified organic under the USDA National Organic Program. OMRI listed products are then eligible to display the OMRI Listed® Seal on their product label or advertising materials.



The OMRI Listed Seal

The OMRI list is a working document that gets updated as additional products are proposed to OMRI.

NOP-National List of Allowed and Prohibited Substances

If you have a product that you want to search to see if it is on the National List of Allowed and Prohibited Substances, please visit the OMRI site:

<http://www.omri.org/omri-lists>

Another directory that lists materials suitable for organic production is managed by the Washington State Department of Agriculture (WSDA):

<http://agr.wa.gov/FoodAnimal/Organic/MaterialsLists.aspx>

Exercise: Review the National List of Allowed and Prohibited Substances and answer the following:

- 1) Name a synthetic substance that is allowed for use in organic crop production...
- 2) Name a non-synthetic substance that is prohibited for use in organic crop production...

Exercise: Go to the OMRI Products List on-line and locate organic herbicides, organic fertilizers and organic insecticides.

However, please note that all materials ultimately need to be approved by your organic certifier (e.g., CCOF) and added to your Organic Systems Plan (OSP) before being applied to your farm.

Keeping Records of your Inputs

The records you keep on pesticide use and other inputs are not only required by the law for organic certification, they will also help you improve your farming operation.

Here are some benefits to recordkeeping:

- Saves money by helping a farmer determine the best IPM program
- Gives precise predictions of how much pesticide you will need in a future year, preventing having to store or dispose of extra organic chemicals
- Prevents over applications and improves rotation decisions
- Helps you evaluate the organic pesticide's effectiveness
- Protects you from legal action if you are accused of improper pesticide use
- Provides data history to respond to public concern regarding pesticide use
- Evaluates the potential of residues as required by organic inspectors
- Evaluates potential environmental liability in the case the land is to be sold or before lenders will loan money

At ALBA, farmers are asked to report all organic pesticide applications monthly in Organic Farming Information Record (OFIR) sheets.

Exercise: Fill out an Organic Farming Information Record (OFIR) sheet with your instructor.

6. Evaluate the Pest Management Program and Improve it When Possible

Evaluating your IPM plan is an important last step. The goal of evaluating your plan is to help you review the decisions made in the IPM process. This requires keeping records and reviewing them on a regular basis. These records allow you to establish measurable goals and measure progress toward achieving your goals. Even the simplest records can usually indicate whether prevention and control strategies have succeeded or if a new approach is needed to improve the plan overall.

Ask yourself the following question to evaluate your IPM:

- How did your IPM plan improve the crop quality?
- How did it improve crop marketability?
- How were your crop yields or profits improved?
- Did your IPM plan have an effect of water quality? How?
- Was biodiversity improved? If not, what actions can be taken in the future to improve it?
- How was farmer-to-farmer information exchange increased? If not, how could this be better facilitated next year?
- Describe how you can increase your own education about IPM.

Disease Management

Diseases are another type of agricultural pest which severely threaten crop production and yield. The 6 components of the Integrated Pest Management (IPM) strategy can help to prevent or fight against disease infestation.

Components of IPM for Disease

1. **Prevention.** Smart management decisions can prevent susceptibility to disease.
2. **Disease Identification.** It is critical to correctly identify a disease in order to confirm its cause and plan for the best solutions.
3. **Monitoring.** By identifying a disease and measuring damage, farmers can make better decisions about when and how to apply a control method.
4. **Determining tolerance levels and economic thresholds.** At what point must action be taken to control the disease?
5. **Control Methods.** When possible, use the least impactful cultural, mechanical, biological, and/or natural chemical controls to manage disease.
6. **Evaluating the disease management program** and improve it when possible. This requires keeping records so that one can learn from his or her mistakes and successes!

"The best approach to disease problems is to prevent them. Many good organic gardening practices are natural disease-preventive measures. Keeping soil healthy, keeping plants properly watered, cleaning up the garden, and rotating crops in the vegetable garden are on the list of practices that help discourage disease."

~ Organic Gardener's Handbook of
Natural Insect & Disease Control
(Ellis and Bradley)

1. Prevention.

A successful disease management program requires careful thought in the crop production system in order to prevent and control disease development. Important disease prevention strategies are:

1. Starting with the selection of appropriate disease-free or resistant plant varieties
2. Maintaining a healthy soil with good drainage.
3. Proper irrigation management
4. Having a fertilizer program that results in optimum plant growth
5. Appropriate ground preparation
6. Maintaining appropriate plant density to minimize disease infection and spread
7. Properly thinning and pruning or 'canopy management' can provide optimum air circulation
8. Maintaining a transplant program which minimizes transplant shock
9. Ensuring a clean seedling production program
10. Conducting effective pest monitoring during the season
11. Knowing the harvest and shipping procedures that maximize shelf life and produce quality

2. Disease Identification

The first step in disease management is learning how to diagnose or identify a disease in the field. This requires the farmer to be knowledgeable about:

- a) the disease,
- b) the pathogen that causes the disease (fungus, bacteria, virus or nematode)
- c) how the disease develops,
- d) phases of disease development,
- e) common signs and symptoms of each disease, and
- f) disease management: prevention and control.

a) Disease: A disease is described as an organism that changes the normal state of the plant by disrupting the functions of the plant. Often a disease is caused by disease causing agents (pathogens), environmental factors, inherent defects of the plant, or a combination of these factors.

Appendix C has a list of prevention and control methods depending on the pathogen.

b) Diagnose the problem: Determine which of the four pathogenic microorganisms, fungi, bacteria, virus or nematode, is causing the disease to prevent additional yield loss. Many times simple field observation is not efficient enough to determine the cause of the disease since these microorganisms are not visible to the naked eye; therefore, samples must be sent off for laboratory analysis.

There are 4 types of pathogens that cause disease: Fungus, Bacteria, Virus and Nematodes.

1) Fungi — Fungus is a multi-celled parasitic plant with no leaves, true stems and roots. It lacks chlorophyll; therefore, it depends on the host plant for its survival. It reproduces by spores which are tiny seed-like structures that grow up to 1 mm in size. Mushroom, mold, and mildew are the most observed examples of fungi.



Figure 16. Powdery Mildew is a common fungal disease.

2) Bacteria — Bacteria are mostly single-celled organisms that reproduce through cell division. Bacteria enter the plant through wounds or natural openings. When bacteria infect the plants its population is difficult to control. There are three common symptoms; abnormal growth, leaf spotting, rotting, and wilting. The important distinguishing characteristics of a bacterial infection are the sticky and slimy materials secreted by the bacterial cells that later on become smelly and fishy.



Figure 17. Soft rot bacterial infection of a potato.

3) Viruses — Virus is a strand of DNA or RNA, consisting of a nucleic acid wrapped in a thin coat of protein. It is a very infectious that multiplies itself only within the cells of the living hosts. However, viruses cannot enter a plant by themselves; they must rely on a vector organism that feeds on the plant or introduces the virus via wounds or other openings. Common symptoms of viral disease include: leaf yellowing and distortion, abnormalities in fruit and flower shape, and stunted plant growth.



Figure 18. Pepper Mild Mottle Virus.

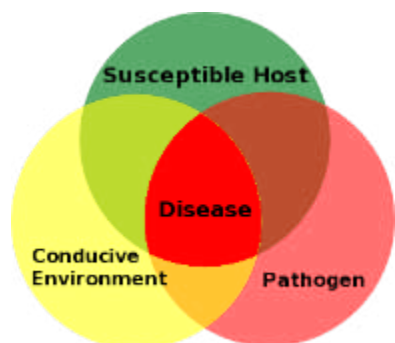
4) Nematodes — Nematodes are unsegmented “worms” that have elongated, rounded, and smooth bodies, pointed at both ends. They are invisible to the naked eye because they are too small and translucent. Plant parasitic nematodes usually live in the soil have sharp mouthparts that are used to puncture the plant’s root walls, injects its saliva, and sucks out its contents, although some also attack bulbs, flowers, and stems.



Figure 19. Root-knot nematode galls.

c) Diagnose the problem: How do diseases develop?

A disease develops when three factors interact; the pathogen (fungi, bacteria, virus, nematode), the host plant, and the environment (weather, nearby plant habitat, wildlife, soil etc.). If any one of these three factors is not present, a disease will not develop. Figure 8 illustrates that the conjunction of the three factors (in red) results in optimal conditions for diseases to develop.



Because a disease is dependent upon all three factors present simultaneously, altering one factor could prevent plant disease. Methods of control serve to alter one of these factors. The column “Minimize Disease Outbreak” in **Table 3** on the next page shows how to modify one or more of the factors to prevent diseases in your crop fields.

Figure 20. The disease triangle.

Table 3. Conditions associated with the three factors of the disease triangle.

Minimize Disease Outbreak	Favor Disease Outbreak
Pathogen	
<ul style="list-style-type: none"> • Low numbers • Susceptible to host resistance • Long life cycle 	<ul style="list-style-type: none"> • High numbers • Not susceptible to host resistance • Short life cycle (multiplies quickly)
Host Plant	
<ul style="list-style-type: none"> • Resistant variety to disease • Grown in proper climate and environment • Grown from certified seed 	<ul style="list-style-type: none"> • No resistance to disease • Grown in unsuitable climate and environment • Not grown from certified seed
Environment	
<ul style="list-style-type: none"> • Temperate climates • Disease free soil • Low density of vectors 	<ul style="list-style-type: none"> • Very wet, dry, shady and cool climates • Disease infected soils • High densities of vectors

Please also note that a pathogen is not always required for a plant disease — the environment alone can cause a plant disease. When this happens, the plant disease is known as **abiotic** because it does not rely on a biological organism to spread the disease. Typical abiotic diseases result from abnormal extreme temperatures, unexpected storm events, droughts, and flooding.

d) Diagnose the problem: Phases of Disease Development

Disease development can be divided into three phases: Arrival, Entry and Multiplication. It encompasses how disease pathogens spread, enter, or multiply in the process of disease development of a potential host plant.

Phase 1 — Arrival Phase-How diseases are spread

Pathogens are spread by wind, insects, water, humans, animals and birds.

Wind disseminates fungus spores from plant to plant in a field or across fields. Pathogens such as leaf and stem rust pathogens are spread long distances by the wind.

Insect vectors with piercing and sucking mouthparts such as aphids and leafhoppers spread pathogens from plant to plant by inserting their mouthparts into the plant when feeding. Some insects with chewing mouthparts such as the spotted and striped cucumber beetle spread bacterial wilt of cucumber and muskmelon.

Water Many pathogens, especially foliar (leaf) pathogens, need a film of water on the plant to begin growth, penetrate the host, and establish infection. Water can carry fungal and bacterial pathogens from field to field, especially in wet and humid weather conditions. When rain splashes water on plants, many fungi and bacteria pathogens can be disseminated very easily via numerous tiny airborne water droplets called **aerosols**. Many bacteria are disseminated long distances in wind-driven aerosols. Water flowing over the surface of fields spreads disease organisms such as Sclerotinia (white mold), *Verticillium*, and downy mildew.

Animals and Birds also may disseminate pathogens. For example, the soybean cyst nematode can be disseminated in the feces of birds; animals may spread water-borne pathogens by walking through an infected crop when the plants are wet.

Human A farmer can locally disseminate bacterial blights, rust and anthracnose by cultivating the crop when it is wet or walking through contaminated fields into uncontaminated fields.

Phase 2 — Entry Phase: How pathogens infect

Vectors are organisms such as insects, mites, nematodes or birds that can introduce a pathogen such as a bacterium or virus into a plant to cause an infection. Vector transmission processes are usually complex and include the transfer of plant viruses by placing a vector's mouthparts (similar to a needle) during feeding. In many other cases, plant parasites are transmitted only after they have multiplied and circulated throughout the body of the vector first. Some pathogens are transmitted into plants from a mother vector to her offspring via her eggs or embryos.

Phase 3 — Multiplication Phase: How pathogens survive

In the Soil — Many pathogens form resistant structures that survive long periods of time in the soil. For example, the *Verticillium* wilt pathogen of potatoes, strawberries, tomatoes and other crops survives for at least several years in the soil.

In Plant Parts — Pathogens may survive on crop refuse on stubble or on the old dead vines. Destroying or burying this crop refuse reduces next year's disease potential.

In Seed and Vegetative Plant Parts — The smuts of small grains survive on or in the seed and survive in storage as long as the seeds remain viable (can germinate). Vegetative plant parts such as tubers, roots and corms provide a mode of survival for many pathogens. Many potato pathogens are carried on or within the tubers.

In Insects and Mites — The bacterial wilt pathogen of cucumber and muskmelon is suspected to overwinter in the digestive tract of cucumber beetles. The wheat streak mosaic virus overwinters in wheat curl mites that survive on winter wheat and some perennial grasses.

In Mild Climates — On the Central Coast of California, the mild winter temperatures often do not kill disease pathogens as in other places with more severe winters. Therefore, certain pathogens survive year-round and populations can grow to high numbers.

3. Monitoring

Yield loss occurs with either decreased crop quality or quantity. Accurate assessment of disease severity and yield loss is made based on the following considerations:

1. The numbers of the disease lesions, pustules, and damage present in the field
2. Pest developmental stage during disease attack
3. Crops development stage during disease attack
4. The number of disease vectors present in the field
5. The duration of the disease attack
6. The amount of healthy plants in the field
7. Market standards and the amount of damage suitable for the market
8. Past and expected weather conditions for a specific season and field location that induces the severity of disease.
9. The size, method and frequency of plant sampling

Monitoring diseases and their environment

Monitoring goes hand in hand with estimating yield loss and is a critical component of an effective IPM program. Monitoring can be **direct** (visually looking for the disease pathogen) or **indirect** (recording environmental conditions which affect disease development).

Direct monitoring of diseases can be based on symptoms or signs of the disease pathogen.

Appendix B gives examples of different disease symptoms and corresponding pathogen.

- Symptoms are visible responses seen on the plant caused by a disease causing agent. Symptoms can be caused by living disease causing agents (biotic) or non-living disease causing agent (abiotic). Living disease agents are blights, rusts, wilts, mosaics, rots, for example. Non-living disease agents are heat, drought, cold, humidity, wetness and air contamination such as dust particles. Often the general symptoms of both living and no-living disease agents on plants are changes in plant color, death of infected tissues, and wilting.
- Signs are the structures produced by disease causing agents such as fungal spores, fungal growths, sooty molds, cankers, galls, slimy ooze, and fishy odor. Signs are more useful in the accurate diagnosis of a disease.

Indirect monitoring of diseases consists of recording environmental conditions which affect disease development. To optimize monitoring and detection of diseases, one should take a random walk through the field and concentrate on those areas where disease is most likely to occur (e.g., , low shady areas with high humidity, field borders, or areas of compact or lush growth).

Monitoring for Disease Distribution in the field is important to know the source of the disease pathogen. If the disease is *seedborne* (carried in or on a seed), for example, in many cases the first diseased plants will be more uniformly distributed in the field. If the disease is *soilborne* (carried in or on the soil), it may often be found in clusters in the field. If the disease is transmitted by insects, the distribution may be more random, or begin more towards the edges of the field (Momol, 2003).

Exercise: Ask an ALBA farmer if you can monitor his field for disease.

Ask if you can sample or collect a plant leaf, stem, fruit or root system with a notable disease symptom. Bring the collected sample into class for evaluation and describe the signs of the disease. If you need a hand lens, please ask your teacher to provide one.

4. Determining tolerance levels and economic thresholds.

At what point must action be taken to control the disease? See Fig. 13: The Economic Threshold Concept

5. Control Methods.

When possible, use the cultural, mechanical, biological, and/or natural chemical control with the least environmental impact to manage disease. Remember the disease triangle (**Fig. 20**)? Prevention is key! Altering the interaction between the host, the environment, and the pathogen, may reduce the risk of disease development.

Important strategies to minimize the incidences of disease include:

1) Site Selection and Preparation Soil-borne diseases remain a major limiting factor for the production of vegetables in California. It is important to start with clean soil and proper sites for crops. Proper decomposition of crop refuse through tillage can reduce pathogen survival and development of diseases in new crops. In general, fallow periods as part of a good rotation can help to reduce pathogen populations. It is also advisable to research the latest practices for eliminating or reducing the number of soil-borne pathogens (e.g., bio-fumigation, anaerobic soil disinfestation and solarization), Avoid soil compaction since this interferes with root growth, encourages soil moisture retention, and promotes root diseases. Planting into beds generally allows for better drainage. Prior to planting, soil should be tested for potential pathogens if appropriate tests are available. Histories of soil-borne disease outbreaks are important in prediction of possible future problems. Planting times can be altered to avoid or reduce development of certain diseases.

2) Plant Host Resistance is the ability of a plant or host to resist infection by a disease pathogen. Resistant varieties can slow down disease development compared to a susceptible variety. However resistance can fail when new races of the pathogen develop.

3) Planting Certified Seed Seed certification happens when a crop is grown from seed produced under carefully controlled conditions and grown in an isolated area to reduce disease potential.

It is important to use only pathogen-free transplants, especially for late blight, bacterial spot, viral diseases, and early blight.

4) Exclusion means keeping the pathogens away. One way pathogens can be excluded is by quarantines that prevent their introduction.

5) Eradication eliminates the pathogen.

6) Crop Rotation is an effective tool for reducing many pathogen populations. When a crop is grown repeatedly on the same land, crop-specific pathogens can increase. Crop rotation involves alternating crop families in a given field over time and helps to keep populations of pathogens at lower levels.

7) Eradicate Alternative Hosts The farmer must consider plants that can be alternative hosts of disease in developing a pest management strategy. For example, disease organisms may spread from nearby crop fields and weeds in and around the field borders.

8) Irrigation Management Excess water damages roots by depriving them of oxygen and creates conditions that favor infection by certain soil-borne pathogens. High soil moisture enhances the development of soil-borne pathogens (e.g., *Phytophthora*, *Pythium* and bacterial wilt pathogens). Use of tension meters or other devices for irrigation scheduling and preventing drainage issues through leveling and ditches can help in disease management.

9) Sanitation The removal of infected crop debris or hosts plants during weeding and harvest can be helpful. Debris destroyed by burning, tillage, sending to the landfill and/or composting are effective ways to reduce the likelihood of disease outbreaks.

In order to reduce dispersal of soilborne pathogens between fields, tools and farm equipment should be cleaned before moving from one field to the next.

10) Protection is the process of protecting plants from disease development or infection. Disease development is greatly slowed down if vegetables are stored in cold storage. Cold storage protects against infection because it is too cold for many pathogens to develop. Protecting seeds and vegetables in isolated areas where vector populations are low and thus easily managed is another way to minimize disease.

11) Culture Practices Farmers should thin plants to appropriate spacing to allow good air circulation. Time of planting may help plants escape disease development. Planting crops early or late before or after periods of high disease potential may minimize disease. Infectious disease can also develop under conditions of drought or fluctuating soil moistures

12) Handling Practices Disease development in storage can be minimized by proper handling practices during the growing season. Proper planting, thinning, pruning, harvesting, and packing procedures with clean and disinfected tools and packing materials will help prevent and control disease.

13) Managing Insect Vectors Insect vectors carry disease organisms such as viruses and bacteria. Managing these insect vectors may reduce the chance of disease. A prime example is the cucumber beetle, vector of the bacterial wilt pathogen of cucumber and muskmelon. The bacterium is carried from plant to plant by the beetle and overwinters in the beetle. A good program for managing the cucumber beetle, started as soon as the plants emerge, will prevent serious losses from the bacterial wilt disease.

In addition to successful management of insect vectors, weeds and other hosts that can serve as a reservoir for both vectors and pathogens must be managed.

14) Fungicides are organic or non-organic chemical compounds or biological organisms used to kill or inhibit fungi or fungal spores. When fungicides are used, the type and the timing are important. For example, in the case of dry bean diseases three different types of fungicides are used for management of each of three major diseases: rust, bacterial blights, and white mold. In each case timing is important and application must be started before the disease is widespread.

15) Quarantine International, State and local quarantines are used to prevent certain agricultural pests from becoming established.

In Monterey County, there is a host-free period for the following crops:

Lettuce, Endive and Escarole — NO plants in the ground from December 7– 21 to manage Lettuce Mosaic Virus

Celery — NO plants in the ground during the month of January to manage Western Celery Mosaic Virus

Exercise: In collaboration with an experienced farmer, remove and properly seal (in a zip-lock bag) a sample of diseased plant material. Deliver the sample to the University of California Cooperative Extension office in Salinas for identification and suggested controls.

Weed Management

A weed is defined as: any plant that is a hazard, nuisance, or harms animals or desired crops. This definition suggests that any plant can be a weed under certain circumstances. Weeds reduce yields, crop quality, and interfere with efficient harvest. (J.A. Ferrell, 2007). Further, poor weed management in one season may lead to weed infested fields for several seasons. The expression commonly heard in English is “One year seeding is seven years’ weeding”!

“In vegetable plantings, weeds can quickly shade out young plants as well as rob the soil of nutrients and water, so weed control is essential--especially when these crops are young.” (Flint, p. 183)

By following Integrated Pest Management principles, a farmer can reduce time and money spent on preventing and controlling weeds in order to provide the best possible economic returns.

Integrated pest management of weeds, like insect IPM, focuses on prevention, identification, monitoring, yield loss, critical weed-free periods, control methods, and evaluation. In organic farming, adequate weed control can be very labor intensive.

“Weeds compete with crop plants for sunlight, water, and nutrients, and their growth must be limited to obtain a reasonable yield of any food crop. Weeds may also interfere with harvesting or other field operations or pose fire hazards. Generally, a weed is defined as “any plant growing where it is not wanted.” Many weedy species can provide benefits in the garden or farm under certain circumstances such as providing food and shelter for insect predators and parasites or keeping dust down. On the other hand, crop plants act as weeds when they are growing where they are not wanted.” (Flint 183)

Components of IPM for Weeds

1. **Prevention.** Smart management decisions can prevent susceptibility to weeds.
2. **Weed Identification.** It is critical to correctly identify a weed in order to plan for the best solutions.
3. **Monitoring.** By identifying weeds and measuring infestation, farmers can make better decisions about when and how to apply a control method.
4. **Estimating critical weed-free periods:** It's important to be knowledgeable about the length of time during which the crop should be practically weed-free to avoid a yield or quality reduction or damage to future crops.
5. **Control Methods.** When possible, use the cultural, mechanical, biological, and/or natural chemical controls with least environmental impact to manage weeds.
6. **Evaluate the weed management program** and improve it when possible. This requires keeping records so that one can learn from his or her mistakes and successes!

1. Prevention.

- Prevent weeds from producing seed. One pigweed plant can produce up to 250,000 seeds and some grasses can produce more than one million seeds. Many weed seeds persist indefinitely in the soil. After four years of intensive management, however, some weed seed populations can be reduced by 90 percent.
- Make sure seed and mulches do not contain weed seeds.
- Rotate crops and choose cover crops that help smother growth of weeds.
- Plan for pre-irrigation and cultivation of sprouted weeds.
- Mow around the field to remove sources of weed seeds.
- Use optimum crop planting densities to shade weeds. If crops intercept 50 percent or more of incoming light, weeds will seldom become a problem. Limitations to increasing crop density include: allowing adequate space for harvest, other field operations and allowing adequate air circulation. However, if weeds germinate anyway, they will be difficult to control with tight spacing.
- Fully compost manures to reduce weed seeds (and possible pathogens).
- Band/distribute fertilizer 2 to 4 inches from the plants rather than broadcasting.
- Establish straight rows and beds far enough apart to avoid injuring crop plants during precision or ridge-till cultivations.
- Hand hoeing may also be practical on some crops. To avoid adverse effects from root damage to the crop, hoeing should be done before the crop and weeds are large.

Prevention: Weed Management Before Planting

The best weed management is prevention before planting and is usually achieved by a combination of two or more of the following methods:

(Adapted from *UC IPM Pest Management Guidelines*: UC ANR Publication 3467 “Weeds,” R. F. Smith, M. LeStrange, S.A. Fennimore)

Prevention methods:

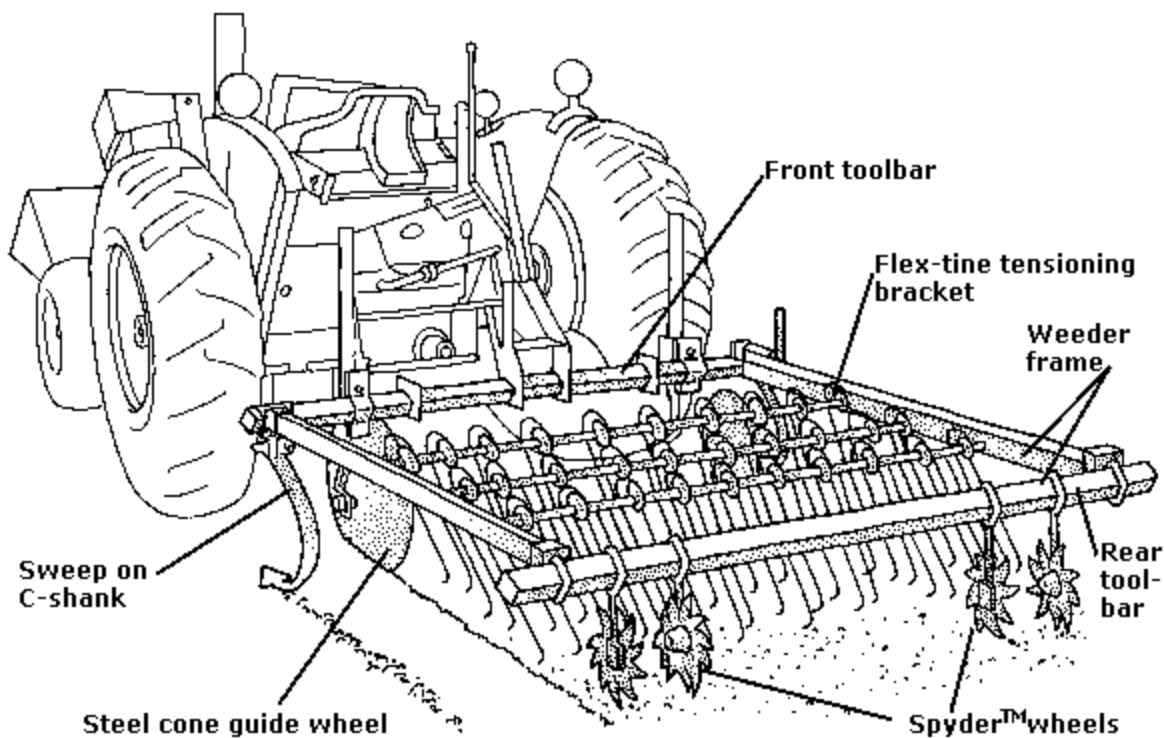
Field selection. Choose fields known to have low weed pressure and few problem weeds. Selection of a field that has low weed pressure will make subsequent weed control operations more efficient and economical.

Sanitation. Weed control in previous crops in the field can dramatically affect weed pressure in subsequent crops. Keeping fields as weed-free as possible and preventing weeds from going to seed in previous crops helps to reduce weed pressure in subsequent crops. This method is often called “clean cultivation”. Ensure all field equipment is free of weed seeds when moving from weedy fields to clean fields. Preventing the introduction of weed seeds into clean fields is an important management strategy

Rotation. Including crops in rotations in which good, season-long weed control is attainable is an important weed control strategy. Likewise, including in a rotation fast-growing crops (e.g., cilantro or salad mix) in which germinated weeds will likely not have enough time to produce seeds before the crop is harvested can be helpful. An effective crop rotation program can help to maintain overall weed pressure at low levels. Some crops due to their architecture are inherently easy or difficult to keep weeded--broccoli, cauliflower, brussel sprouts, and tomatoes are generally considered easier because they are fast growing, shade out weeds, and the majority of the weeding can be done mechanically. On the other hand, a crop like carrots can be difficult to weed because there can be many weeds within a dense seed line that need to be managed by hand.

Land preparation. A well-prepared seedbed that is free of large clods permits precision planting with rapid and uniform emergence of plant seedlings. Straight beds and seed lines help allow easy tractor cultivation of weeds.

Blind, “over-the top” cultivation controls very small weeds, just germinated or emerged, before and sometimes after planting. The entire surface of the field is worked very shallow using flex-tine cultivators (e.g. Lely weeder), or rotary hoes.



- Shallow between-row cultivators such as basket-weeders, beet-hoes, or small sharp sweeps are used to cut off and uproot small weeds after the crop is up. These can get very close to the crop when it's small, without moving much soil into the row, and may be the only tools used on delicate crops like leafy greens.



Lilliston-style cultivator

- As vigorous crops grow, soil can be thrown into the row to bury in-row weeds using rolling cultivators (e.g. Lilliston-style cultivator), spider wheels (e.g. Bezzerides), large sweeps or hilling disks. Some of these tools can be angled to pull soil away from the row when plants are small, and later turned around to throw soil back on the row during subsequent cultivations.



Pre-irrigation. It can be helpful to pre-irrigate before seedbed preparation or pre-irrigate prepared seedbeds. Pre-irrigation on prepared beds followed by shallow cultivation, flaming or even steaming can kill an initial flush of weeds and create a “stale seedbed”. If cultivating, try not to work the soil too deeply in order to avoid bringing up soil from greater depths that may contain weed seeds. For organic fields or for weedy fields, pre-irrigation can be repeated several times to deplete the weed population. One strategy successfully employed at ALBA and in the Salinas Valley involves listing beds (i.e., creating “hills and furrows with large shovels pulled by the tractors), pre-irrigating, waiting for a period of time (typically 7–14 days) to achieve a flush of weeds, and then using the Lilliston-style cultivator to remove the weeds.

Solarization. Soil solarization can be used to control most weeds in vegetable crops grown in certain warmer parts of California. This is typically accomplished on fields by covering the soil for an extended period of time with plastic (clear plastic being the most effective in raising the soil temperature to lethal levels for weeds). Solarization sometimes requires a summer fallow for treatment and may work best with a fall-planted crop.

Organic herbicides. Organic herbicides are occasionally used on organic farms to prevent and control weed problems. However, their use tends to be limited to specialized applications (e.g., places where it is difficult to perform mechanical cultivation like around hydrants). Also, organic herbicides can be cost-prohibitive and non-selective (i.e., can damage crops being grown)

1. Weeds may be identified and classified as grasses, broadleaves, and sedges.

Grass Weeds have hollow, rounded stems and nodes (joints) that are closed and hard. The leaf blades have parallel veins, are much longer than they are wide, and alternate on each side of the stem. Some examples are crabgrass, goosegrass, crowfootgrass, sandbur, annual bluegrass, torpedograss, and vaseygrass.

Broadleaf Weeds are a highly variable group of plants but most have showy flowers and net-like veins in their leaves. They are easy to separate from grasses due to their generally different leaf structure and habits of growth. Some examples of broadleaf weeds are cudweed, creeping charlie, henbit spurges, malva, pennywort, creeping beggarweed, cocklebur, sicklepod, and Florida beggarweed.

Sedges are an important group of “grass-like” weeds, but they are not true grasses. They are characterized by a solid, triangular-shaped stem with leaves extending in three directions and are usually referred to as nutgrass. Annual sedges (often called water grass) are usually a minor problem and easier to control than perennial sedges. There are two major perennial sedges: yellow and purple nutsedge.

2. Weeds may further be classified by the length of their life cycle (annual, biennial, perennial).

Annual weeds complete their life cycle within one year. They germinate from a seed, then produce more seed, and finally die in 12 months or less. They may be annual grasses, sedges, or broadleaved weeds. In addition, their life cycle may begin at different seasons of the year. Summer annuals emerge in the spring and mature before winter, and winter annual weeds sprout from seed in the fall, and complete their life cycle before summer of the next calendar year. Examples of summer annual weeds are crabgrass, yellow foxtail, and cocklebur. Some winter annual weeds include wild radish, henbit, annual bluegrass, and chickweed

Examples of Annual Weeds:

Low Amaranth, *Amaranthus deflexus*



Figure 21. (UC IPM Online, 2000)

Little Mallow, *Malva parviflora*



Figure 22. (UC IPM Online, 2000)

Biennial weeds have a 2-year life cycle. They germinate from seed in the fall, develop large root systems and a compact cluster of leaves during the first year. The second year they mature, produce seed, and die. Examples of biennial weeds are cudweed, Carolina false dandelion, wild carrot, and bull thistle.

Examples of Biennial Weeds:

Poison Hemlock, *Conium maculatum*

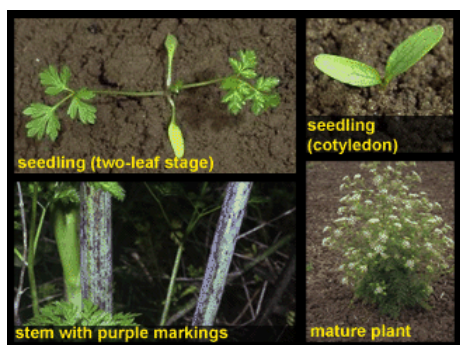


Figure 23. (UC IPM Online, 2000)

Scotch thistle, *Onopordum acanthium*



Figure 24. (UC IPM Online, 2000)

Perennial Weeds

Weeds that live more than two years are perennials. They reproduce by vegetative parts such as tubers, bulbs, rhizomes (underground stems) or stolons (above-ground stems). Some also produce seed in addition to vegetative reproduction. During the winter season, most survive in a dormant state, and many lose their above ground foliage and stems. With the beginning of spring, they regenerate from food reserves in their root systems. Perennial weeds are the most difficult to control because of their great reproductive potential and persistence. Torpedograss, nutsedge, johnsongrass, and common bermudagrass are members of this group of weeds. (*Principles of Weed Management*¹ J.A. Ferrell, G. E. MacDonald, B. Sellers, and C. Rainbolt²)

Examples of Perennial Weeds:

Foxtail barley, *Hordeum jubatum*

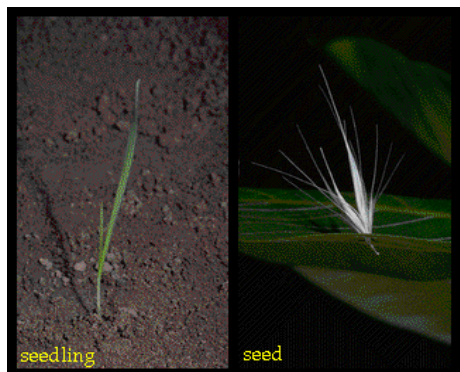


Figure 25. (UC IPM Online, 2000)

Yellow Nutsedge, *Cyperus esculentus*



Figure 26 (UC IPM Online, 2000)

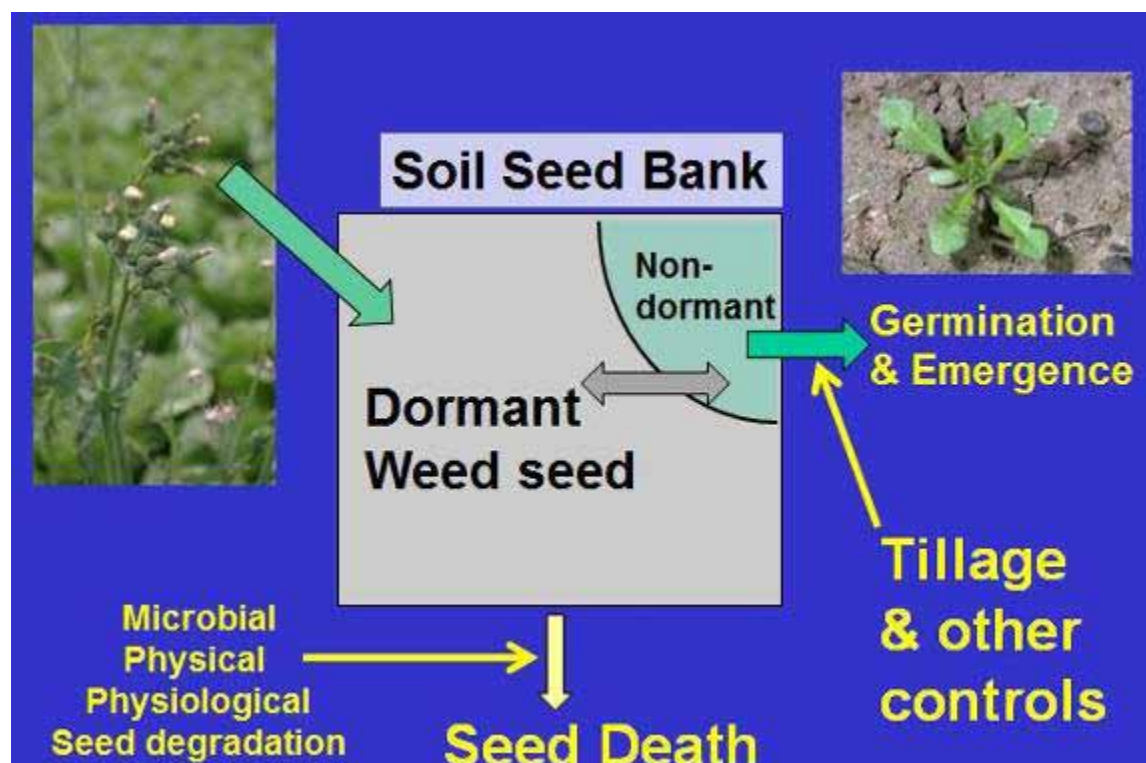
Exercise: Collect an unknown weed with its root system from a crop field at ALBA. Shake off the soil from the roots and then place it on a paper towel. Try to identify your weed at the University of California IPM Online Website at: <http://www.ipm.ucdavis.edu/TOOLS/TURF/PESTS/beginkey.html>

Weed photo Gallery: http://www.ipm.ucdavis.edu/PMG/weeds_common.html

3. Monitoring.

Differences in weed populations are due to site location, soil type, associated habitat type, and other factors that require a farmer to understand which weeds are present in the field. Frequently monitoring helps to identify the species of weeds that are present.

Seeds can remain viable in the soil for many years in 'seed banks' and cause recurring problems in fields.



Seed banks in a field usually reflect the types of weeds that have been present in previous years. This is important information for a farmer in order to select the specific types of weed prevention and control measures that will be used. Field observation and knowing what weeds have been present in previous years is an important monitoring strategy. Sometimes repeated deep tillage on ground new to cultivation is necessary to eliminate perennial weeds.

4. Estimating critical weed-free periods:

It's important to be knowledgeable about the length of time during which the crop should be practically weed-free to avoid a yield or quality reduction or damage to future crops.

Determining economic thresholds for weeds is often done through estimating **critical weed-free periods** (i.e., the relative time a crop must be weed free to avoid crop yield losses). In general, early weeds that emerge at the same time as the crop will cause more yield loss than weeds emerging after the crop is established.

Critical Weed-free Period for Horticultural Crops	
Crop	Critical Weed-free Period
Beets	First 2-4 weeks after emergence
Cabbage,	First 3 weeks after planting
Carrots	First 3-6 weeks after emergence
Cucumbers,	First 4 weeks after seeding
Lettuce	First 3 weeks after planting
Onions	First the whole season
Potatoes	First 4 weeks after planting
Squash	Early plantings compete better
Strawberries,	During May and June
Tomatoes, fresh	First 36 days after transplanting
Tomatoes, seeded	First 9 weeks after seeding

5. Control Methods.

Crop stand. Some vegetable crops stands are uniform and better able to compete against weeds. Gaps in the stand provide space for weeds to become established before the crop canopy grows and completely shades the soil.

Biological control. Few specific systems of biological control have been introduced for control of weeds in agriculture, and none for row crops. Naturally, some weed seeds in the soil may be attacked by insects, bacteria, fungi, nematodes, etc. and maintaining a healthy soil biota is likely helpful. For more information on Weed Feeders visit the following link: <http://www.nysaes.cornell.edu/ent/biocontrol/weedfeeders/wdfdrtoc.html>

Cultivation is an effective method of weed control. Good bed preparation is essential to allow close cultivation. Repeated shallow cultivations dislodge small weed seedlings that emerge irrigations or rainfall. Adjust cultivators to disturb only a shallow layer of soil to minimize bringing weed seeds up from deeper layers. Timeliness in cultivation is essential. Seedlings are easier to kill than larger weeds.

Hand-weeding is an expensive component of the crop production budget. If a weeding crew is sent into a field immediately before harvest when weeds are mature, weed removal is typically slow and expensive. Ideally, good cultural practices will result in minimal hand-weeding requirements.

Weed control using crop rotations

- Try to alternate crops with different tillage requirements or time of planting.
- Grow fast-growing, dense winter cover crops like cereal rye that can prevent weeds from germinating, suppress weeds and limit weed seed production

Managing your weed seed bank

- keep weeds from going to seed.
- Reduce weed influx by keeping field borders mowed and trimmed.
- Power wash tillage equipment after use in fields.

Weed control by manipulating fertilizer placement and timing.

- Avoid Pre-Plant Broadcasting Of Soluble Nutrients That May Be More Readily Utilized By Fast-Growing Weeds Than Slow-Growing Crops, And May Even Stimulate Weed Germination.

Efficient weed control through mechanical seeding

- Plant in straight rows that can be easily cultivated in the future.
- Uniform row spacing across comparable crops makes future cultivation easier.
- Consider multiple-row units; gauge wheels are helpful on wide units or if fields aren't level.
- With frequently used tractor-mounted cultivators, get them set just right and leave them on all season to avoid repeated mounting and adjustment.

Managing your weeds with irrigation

- Assure that irrigation is largely limited to the crop seed line, i.E. Drip irrigation.

Weed control and cover crops

- Select cover crop species for rapid growth that can starve weeds of light and nutrients. At alba, rye or a grain-legume mix are popular in the winter. Buckwheat, sorghum, or sudangrass are summer options .
- Drill the seed and even irrigate if necessary to assure thick stands and rapid establishment of cover crops.

Crop rotation for managing weeds

- Rotations may include short-season crops in areas infested with perennial weeds like nutsedge; and/or choosing densely seeded cereal cover crops for weed shading.

Weed control using flame weeders

- Prepare soil for planting, pre-irrigate, then use a flame weeder to kill *very small* weeds without disturbing the soil.
- One or two flamings are often used, just before and/or after planting, but prior to crop emergence. Timing is vital — flaming will likely not control established weeds.
- Single burners flame just the crop row, multiple burner units can cover a whole bed.
- Backpack, push-type and tractor-mount weed-flaming units are all used.

Take some risks and experiment with new ideas

- Start on a small scale with tools and techniques that are proven by others and possibly new to your farm.
- Identify your problem weeds and compare different combinations of rotations, cover crops, and cultivation tools for their effectiveness in providing control.
- Keep an eye out for new tools, or new ways to use old tools.
- Consider leaving a “control” row or section untreated, so you can see the effectiveness of your tactics.

Vertebrate Pest Management

Vertebrates are a major taxonomic group that includes mammals, birds, reptiles, amphibians, and fishes — all of which have important roles in natural and agricultural ecosystems. As pests, it is typically mammals and birds that cause the most concern for farmers.

Organic farmers usually employ a holistic approach to control vertebrate pest populations with a goal of keeping populations at tolerable levels rather than total elimination, as opposed to simply using chemical poisons. Controls can take the form of habitat modification, introducing natural predators, exclusion, frightening, repellents, and trapping. For example, to manage gophers an organic farmer might use some combination of the following: owl boxes, specialized traps, timely tillage to disrupt burrows and control non-crop food sources, and even releasing gopher snakes!

At ALBA, farmers mainly have to contend with two vertebrate pests — gophers and ground squirrels. However, occasionally hares, voles and moles also cause minor damage. Deer have occasionally been seen near the ranch. Birds have been a problem by eating cover crop seed, damaging young transplants, and causing damage by pecking at harvestable crops.

The following information is gathered largely from UC IPM on-line publications, Thomas Wittman (Gophers Limited), and also ALBA's own experience at managing these pests.

Gophers

Pocket gophers, often called gophers, *Thomomys* species, are burrowing rodents that get their name from the fur-lined, external cheek pouches, or pockets, they use for carrying food and nesting materials. Pocket gophers are well equipped for a digging, tunneling lifestyle with their powerfully built forequarters; large-clawed front paws; fine, short fur that doesn't cake in wet soils; small eyes and ears; and highly sensitive facial whiskers that assist with moving about in the dark. A gopher's lips also are unusually adapted for their lifestyle; they can close them behind their four large incisor teeth to keep dirt out of their mouths when using their teeth for digging.



Identification

Five species of pocket gophers are found in California, with Botta's pocket gopher, *T. bottae*, being most widespread. Depending on the species, they are 6 to 10 inches long. For the most part, gophers remain underground in their burrow system, although you'll sometimes see them feeding at the edge of an open burrow, pushing dirt out of a burrow, or moving to a new area.

Mounds of fresh soil are the best sign of a gopher's presence. Gophers form mounds as they dig tunnels and push the loose dirt to the surface. Typically mounds are crescent or horseshoe shaped when viewed from above. The hole, which is off to one side of the mound, usually is plugged. Mole mounds are sometimes mistaken for gopher mounds. Mole mounds, however, are more circular and have a plug in the middle that might not be distinct; in profile they are volcano-shaped. Unlike gophers, moles commonly burrow just beneath the surface, leaving a raised ridge to mark their path.

Gopher mound (unplugged)



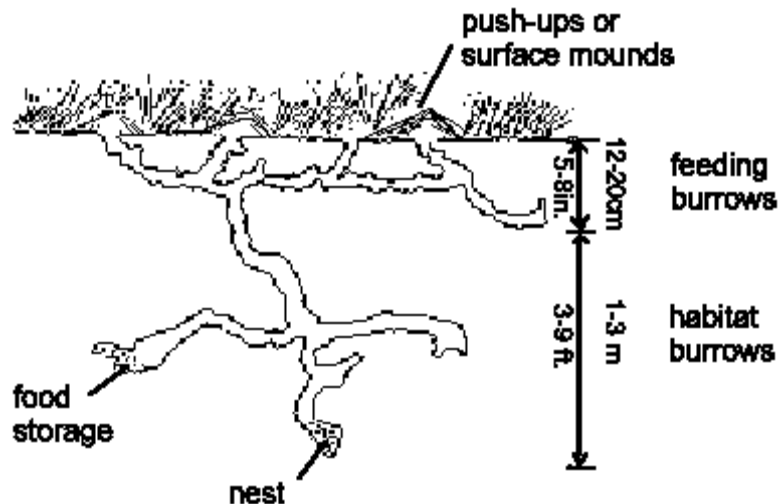
vs. mole mound



One gopher can create several mounds in a day. In non-irrigated areas, mound building is most pronounced during spring or fall when the soil is moist and easy to dig. In irrigated areas such as crop fields, lawns, flower beds, and gardens, digging conditions usually are optimal year round, and mounds can appear at any time. In snowy regions, gophers create burrows in the snow, resulting in long, earthen cores on the surface when the snow melts.

Biology and Behavior

Pocket gophers live in a burrow system that can cover an area that is 200 to 2,000 square feet. The burrows are about 2 ½ to 3 ½ inches in diameter. Feeding burrows usually are 6 to 12 inches below ground, and the nest and food storage chamber can be as deep as 6 feet. Gophers seal the openings to the burrow system with earthen plugs. Short, sloping lateral tunnels connect the main burrow system to the surface; gophers create these while pushing dirt to the surface to construct the main tunnel.



Gophers don't hibernate and are active year-round, although you might not see any fresh mounding. They also can be active at all hours of the day.

Gophers have an important role to play in any ecosystem. They aerate and redistribute soil (e.g., a single animal moves several tons of soil in a year), incorporate organic matter, inoculate soil with beneficial microorganisms, and are a food source for predators like snakes and owls.

Gophers usually live alone within their burrow system, except when females are caring for their young or during breeding season. Gopher densities can be as high as 60 or more per acre in irrigated alfalfa fields or in vineyards. Gophers reach sexual maturity at about 1 year of age and can live up to 3 years. In nonirrigated areas, breeding usually occurs in late winter and early spring, resulting in 1 litter per year; in irrigated sites, gophers can produce up to 3 litters per year. Litters usually average 5 to 6 young.

Pocket gophers are herbivorous and feed on a wide variety of vegetation but generally prefer herbaceous plants, shrubs, and trees. Gophers use their sense of smell to locate food. Most commonly they feed on roots and fleshy portions of plants they encounter while digging. However, they sometimes feed aboveground, venturing only a body length or so from their tunnel opening. Burrow openings used in this manner are called "feed holes." You can identify them by the absence of a dirt mound and by a circular band of clipped vegetation around the hole. Gophers also will pull entire plants into their tunnel from below. In snow-covered regions, gophers can feed on bark several feet up a tree by burrowing through the snow.

Damage

Gophers can devastate agricultural crops if populations are left unchecked. They can also damage irrigation tubing.



Trapping

In an organic system, it is not permitted to use chemical poisons to control gophers. Trapping is a safe and effective method for controlling pocket gophers. Several types and brands of gopher traps are available. The most common type is a two-pronged, pincher trap such as the Macabee, Cinch, or Gophinator, which the gopher triggers when it pushes against a flat, vertical pan. Another popular type is the choker-style box trap.

To set traps, locate the main tunnel with a probe, as described above. Use a shovel or garden trowel to open the tunnel wide enough, in the case of the Macabee-type, to set traps in pairs facing opposite directions. Placing traps with their openings facing in opposite directions means you will be able to intercept a gopher coming from either end of the burrow. The box trap is easier to use if you've never set gopher traps before, but setting it requires more surface excavation than if you are using the pincher-type traps, an important consideration in lawns and some gardens. However, box traps can be especially useful when the diameter of the gopher's main tunnel is smaller than 3 inches, because in order to use the pincher-type traps, you will need to enlarge small tunnels to accommodate them. This can add time to the trapping process.

It isn't necessary to bait a gopher trap, although some claim baiting might give better results. You can use lettuce, carrots, apples, alfalfa greens, or peanut butter as bait. Place the bait at the back of a box trap behind the wire trigger or behind the flat pan of a pincher-type trap. Wire your traps to stakes so you can easily retrieve them from the burrow.

After setting the traps, you can exclude light from the burrow by covering the opening with dirt clods, sod, canvas or landscape cloth, cardboard, or plywood. You can sift fine soil around the edges of these covers to ensure a light-tight seal. Alternatively, you can leave the trap-sets uncovered, thereby encouraging gophers to visit these trap sites as they seek out these openings to plug; gophers do not like open systems.

The influence on capture success of covering versus uncovering trap-sets is unclear, although current data suggests there might be little difference. Leaving trap-sets uncovered will allow you to set traps more quickly and check them more easily. However, you always should cover sets when using box traps, since gophers likely will plug tunnels before hitting the trigger wire of these traps if you leave them uncovered.

Check traps often and reset when necessary. If you haven't captured a gopher within 2 days, reset the traps in a different location.

Trapping tips:

Set traps in early morning or late afternoon (makes easier to find most recent trap, as disturbed soil often has moist appearance)

- Be sure to trap all year as in winter breeding population is lowest
- Check traps often
- Wear gloves
- Trap in freshest burrow (try to figure direction of travel of gopher)
- Stake traps to find them and keep them in place

ALBA's Recommendation: Cinch Trap

The Cinch trap has proven to be one of the most effective and humane ways of eliminating gophers at ALBA. It has the advantage of not having to excavate a large hole and further damage crops in its placement. Also, it is very easy to remove the dead gopher from its grip.

The following is a simple visual guide for setting a Cinch trap:

STEP ONE



STEP TWO

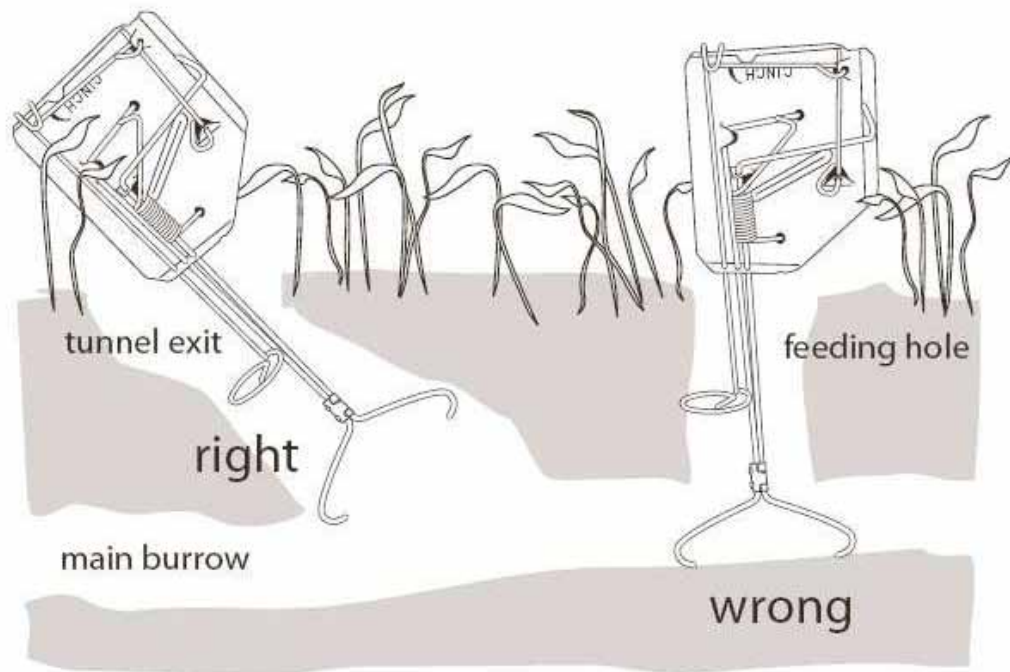


STEP THREE



STEP FOUR





STEP FIVE



STEP SIX

Release gopher from trap and place back in hole. Bury the carcass.



Other Controls

1. Creating habitat for predators

There are many predatory species that can be encouraged onto the farm that can help in reducing gopher populations. Raptor perches and owl boxes can be built. One barn owl family can eat up to one thousand gophers per season; however, barn owls often have a large range and just a few gophers in a farm field can cause considerable damage. Therefore, trapping is also necessary. Other predators include dogs, cats, coyotes, and snakes.



2. Habitat modification

Reducing non-crop food sources, especially annual weeds on field margins, can help reduce food sources. Several nutsedge species (e.g., *Cyperus esculentus* and *C. rotundus*) are preferred foods for gophers.

Timely tillage with a chisel plow or ripper can destroy burrows and help push the gophers out of the field. Gophers typically re-inhabit the field starting from the field edges.

Plants disagreeable or noxious to gophers can be planted. Planting gopher purge (*Euphorbia lathyris*) around field borders is said to help repel gophers.

3. Do nothing

Because no population will increase indefinitely, one alternative to a gopher problem is to do nothing, letting the population limit itself. This, however, can lead to serious crop losses. Also, since your field may border a neighbor's operation, harboring large gopher populations can result in ill feelings.

Ground Squirrel

The California ground squirrel, *Spermophilus beecheyi*, is the most common species and can be very troublesome for farmers. This squirrel's habitat includes nearly all regions of California except for the Owens Valley, located in the southeastern part of the state, southward into the desert regions.



Identification

It is easy to identify ground squirrels, since they forage aboveground near their burrows. Their body measures 9 to 11 inches, while their semi-bushy tail adds another 5 to 9 inches in length. Their fur is brownish gray and speckled with off white along the back; the sides of the head and shoulders are light gray to whitish. One subspecies that inhabits most of Northern California has a dark, triangular-shaped patch on its back between the shoulders; this patch is missing from other species.

Although ground squirrels look similar to tree squirrels and can climb trees, when frightened they always will retreat to a burrow, whereas tree squirrels will climb a tree or tall structure and never use a burrow.

Biology and Behavior

Ground squirrels live in a wide variety of natural habitats but usually avoid thick chaparral, dense woods, and wet areas. Populations can be particularly high in grazed rangelands and in areas disturbed by humans such as road or ditch banks, fencerows, around buildings, and in or bordering many crops.

Ground squirrels live in a burrow system where they sleep, rest, rear young, store food, and avoid danger. The burrow openings are about 4 inches in diameter but can vary considerably. The burrows can be 5 to 30 feet or more in length and can extend 2 to 4 feet below the soil surface. Often there is more than one opening in a burrow system. Ground squirrels live in colonies that can include several dozen animals in a complex of burrows. More than one squirrel can live in a burrow.

Ground squirrels are active during the day, mainly from midmorning through late afternoon, especially on warm, sunny days. Ground squirrels have two periods of dormancy during the year. During winter months most ground squirrels hibernate, but some young can be active at this time, particularly in areas where winters aren't severe. During the hottest times of the year

most adults go into a period of inactivity, called estivation, that can last a few days to a week or more. During these periods, the burrow appears open at the entrance, but the squirrel plugs it with soil near the nest.

Ground squirrels breed once a year, averaging 7 to 8 per litter. Timing of breeding varies with location. In Southern California breeding begins in December, in the Central Valley the time-frame is February through April, and in the mountain ranges breeding begins somewhat later. Aboveground activity by adults is at a maximum at the height of the breeding season. The young are born in the burrow and grow rapidly. When they are about 6 weeks old, they usually emerge from the burrow. At 6 months they resemble adults.

Ground squirrels are primarily herbivorous, and their diet changes with the season. After emerging from hibernation, they feed almost exclusively on green grasses and herbaceous plants. When annual plants begin to dry and produce seed, squirrels switch to seeds, grains, and nuts and begin to store food. Ground squirrels usually forage close to their burrows. Their home range typically is within a 75-yard radius of their burrow.

Damage

Ground squirrels damage many food-bearing plants. Particularly vulnerable are grains as well as nut and fruit trees such as almond, apple, apricot, orange, peach, pistachio, prune, and walnut. Ground squirrels will devour vegetables in the seedling stage. They can damage young shrubs, vines, and trees by gnawing bark, girdling trunks (the process of completely removing a strip of bark from a tree's outer circumference), eating twigs and leaves, and burrowing around roots.

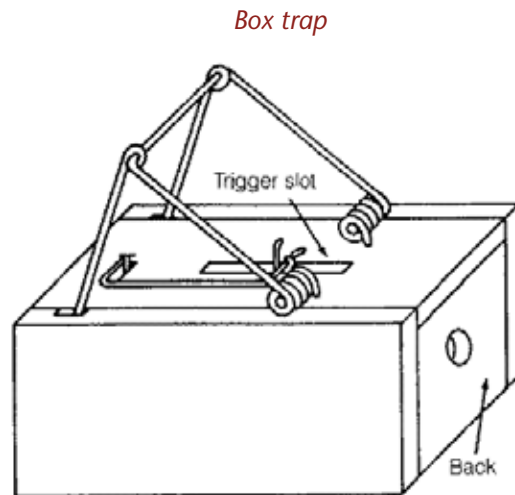


Ground squirrels will also gnaw on irrigation lines.

Ground squirrels can harbor diseases harmful to humans, particularly when squirrel populations are numerous. A major concern is bubonic plague transmitted to humans by fleas that the squirrels carry. Ground squirrels are susceptible to plague, which has wiped out entire colonies. If you find unusual numbers of squirrels or other rodents dead for no apparent reason, notify public health officials. Do not handle dead squirrels under these circumstances!

Trapping

There are several types of traps that kill ground squirrels, including box traps, tunnel traps, and Conibear traps. For box and tunnel traps, place them on the ground near squirrel burrows or runways, and bait them with walnuts, almonds, oats, barley, or melon rinds. Place the bait well behind the trigger or tied to it.



Conibear trap



After you bait the traps, don't set them for several days, so the squirrels become accustomed to them. After the squirrels are used to taking the bait, rebait and set the traps.

To reduce hazards to children, pets, poultry, and non-target wildlife, place box-type traps in a covered box with a 3-inch diameter entrance. Put the box near active burrows with signs of recent diggings. Inactive burrows will be filled with leaves or old straw or have cobwebs across the entrance.

The Conibear trap No. 110 with a 4 ½– by 4 ½–inch jaw spread also is an effective kill trap. You can bait the wire trigger, but usually you'll want to leave it unbaited. Place the trap directly in the burrow opening, so the squirrel must pass through it, tripping the trigger.

It might be necessary to use soil to partially fill in the burrow entrance around the outer edges of the trap to prevent the squirrel from slipping around the outside of the trap. Closing all other burrows with soil might hasten success by directing the squirrel to the remaining open burrow, which contains the trap. Attach the Conibear trap to a stake to prevent a scavenger from carrying off both it and the squirrel. With this type of trap, leaving the trap baited but unset has little effect on trapping success.

Inspect traps at least once a day, and remove dead squirrels. Don't handle the carcasses without protective gear; you can use a plastic bag slipped over each hand and arm as a glove. Once you have removed the squirrel from the trap, hold the animal with one hand and turn the bag inside out while slipping it off your arm and hand. If possible, keep small children and pets out of the area while traps are in use. In kit fox areas, spring all Conibear traps before nightfall and reset them the following morning.



**ALBA's recommendation:
Black Fox Repeating Live Trap**

There are trap designs that permit the catching of several squirrels with a single baiting. The live squirrels can then be euthanized inside the trap by drowning or carbon monoxide poisoning from a car's exhaust pipe.

Flooding

Farmers can direct irrigation water with sprinkler pipes and flexible main line down into squirrel burrows. This is best accomplished with a team of individuals standing at different burrow exits to strike and kill the fleeing squirrels with shovels or other hard objects.

Shooting

Shooting squirrels with a .22 rifle can provide some control, but it is very time consuming. Shooting is recommended only when you can do it safely and you are in a rural location where squirrel numbers are very low. Please note, guns are **NOT** permitted at ALBA and this information is being provided for educational purposes only. There are no effective "frightening" devices or repellents that will cause ground squirrels to leave their burrows or avoid an area or crop.

Habitat Modification

You'll generally find ground squirrels in open areas, although they sometimes use available cover. Remove brush piles and debris to make an area less desirable. This also aids in detecting squirrels and their burrows and improves access during control operations.

Ground squirrels can reinvade a site by moving into vacant burrows. Destroy old burrows by deep ripping them to a depth of at least 20 inches, using a tractor and ripping bar(s). Simply filling in the burrows with soil does not prevent reinvansion, as ground squirrels easily find and reopen old burrows.

Natural Control

Many predators, including owls, hawks, eagles, rattlesnakes, and coyotes, eat ground squirrels. ALBA has installed “owl boxes,” essentially a large bird house designed specifically for owls, which in all cases have eventually been inhabited by owls for some period of time. The accumulation of “owl pellets,” hairballs that include bones of the vertebrate pest, are proof of some level of natural control.

Follow-up

For those who live next to wildlands or other areas where squirrels are common, an ongoing control program will be necessary, since squirrels will reinvade over time. Once you have controlled ground squirrels, periodically monitor the area for re-infestation. Check for new burrows, and start control actions as soon as you notice new arrivals. It is easier and less expensive to control a small population.

Resources

The Internet Center for Wildlife Damage Management

- non-profit that provides research-based information on how to responsibly handle wildlife damage management; excellent on-line guides

University of California, Vertebrate Integrated Pest Management

- on-line resource for a variety of vertebrate pest management
<http://www.ipm.ucdavis.edu/PMG/menu.vertebrate.html>

The National Sustainable Agriculture Information Service (ATTRA) — Fayetteville, AR
(800) 346-9140 English, (800) 411-3222 Spanish

- general technical help for organic/sustainable farming; a library of on-line publications
vertebrate publications on deer control options
<http://www.attra.ncat.org/pest.html#vertebrate>

Gophers Limited — Felton, CA (831) 335-2400

- information on non-chemical vertebrate pest management on website; also offers workshops and sells Cinch traps
<http://www.gopherslimited.com/>

The Hungry Owl Project — San Anselmo, CA (415) 454-4587

- non-profit education and wildlife rehabilitation center in Marin County that sells owl boxes; also has on-line resources on owls and other beneficial predators
<http://www.hungryowl.org/index.html>

The Trap Maker — Red Bluff, CA (530) 529-1910

- maker of Black Fox repeating trap for ground squirrels
<http://www.thetrapmaker.com>

Appendix A. Insect Orders and Typical Characteristics of Each Order

There are 20 insect orders which are listed in the key below:

1. **Coleoptera** — This is the largest order of insects. They have biting mouthparts and hard forewings.
2. **Collembola** — Small insects with no wings and long legs used for jumping. Most live in soil.
3. **Dermaptera** — Insects with biting mouthparts and long antennae. Most live in rotting plants.
4. **Dictyoptera** — Insects that lay their eggs in enclosed capsules called oothecae.
5. **Diptera** — Insects with 2 wings and compound eyes. Their mouthparts may be the sucking kind or the sponge-like absorbing kind.
6. **Ephemeroptera** — The most primitive winged insect. They have short antennae. Their nymphs live in fast flowing water.
7. **Hemiptera** — Insects with unusual heads. The head has a snout used for piercing and sucking. The wings are usually hard and held flat against the body. The bottom portion of their wings near their body is leathery, and the tip of their wings is membranous.
8. **Homoptera** — Insects with piercing/sucking mouthparts. Their wings are membranous from base to tip. These insects feed exclusively on plants.
9. **Hymenoptera** — Insects with 4 wings, long legs, and compound eyes. Their mouthparts may be sponging, sucking, or biting.
10. **Isoptera** — The name Isoptera comes from the latin *iso* which means equal because both the front and hind wings of these insects are about the same size.
11. **Lepidoptera** — The name comes from *lipido* which means scale. The wings of these insects are covered by small, overlapping and often colorful scales. Most have sucking mouthparts.
12. **Neuroptera** — Insects with large, membranous wings with a dense network of veins.
13. **Odonata** — Insects with 2 pairs of wings and biting mouthparts. Most have thin legs and short antennae. Their heads are small, and their large compound eyes nearly cover their heads. Their nymphs live in water.
14. **Orthoptera** — These insects have a variety of shapes and characteristics. The one thing that they have in common is that they all move with great agility. Their wings fold over their body when not in use. Some of the females in some of the species in this class are wingless.
15. **Plecoptera** — Insects that are flat, with large wings and biting mouthparts. Their larvae live in water.
16. **Protura** — Primitive insects with no eyes, antennae, or wings. They live in soil.
17. **Psocoptera** — Small insects with long antennae and biting mouthparts.
18. **Siphonaptera** — Insects with long legs for jumping and sucking mouth parts.
19. **Thysanura** — Insects with soft, flat bodies. They are colorless. They are called bristletails and have short legs but move very rapidly.
20. **Trichoptera** — Insects with long antennae and legs. They have hairs on the surface of their wings.

Appendix B. Symptoms of Disease by Pathogen

Symptoms and signs of fungal diseases

Blight (Fig 27) are the appearance of streaks on leaves, stems, and fruits that include early and late blights that mostly attack tomatoes, potatoes, eggplant, pepper, and their relatives. Blight is a disease condition where an affected plant part is dried or dead but not rotten and has yellow or dead tissues. It also cause any sudden, severe, and extensive spotting, discoloration, or destruction of leaves, flowers, stems, or the entire plants and usually attacking young, growing tissues. The disease names are often coupled with the names of the affected part of the host; e.g., leaf blight, blossom blight, shoot blight, stem blight.



Figure 27. Early Blight.
Photo Courtesy of the
University of Minnesota

Cankers are dead areas on a stem or fruit surrounded by living cortical tissues. (Fig. 28)



Figure 28. Cankers on an Ash
Tree (Photo courtesy of Roger
Griffith, 2008)

Club roots are the large swelling of roots, stunted growth or death. Many secondary organisms invade the roots through the galls, leading to crop death. It is a major disease of the brassica family of crops. (Fig. 29)

Damping-off kills seedlings before soil emergence as well as the newly emerged ones. The stem rots occurred right on the soil line and the plant wilts and falls over and dies.

Galls are outgrowths or swellings of fast growing plant cells.

Mildews are the white spots or patches on leaves, shoots, and other plant parts. Downy mildew kills the infected plant fast, while powdery mildew causes stunted growth, stressed plant, and reduced yield but not killing the plant.

Root rots (Fig. 30) are the killing of the rootlets that cause stunting and wilting.

Rusts are the orange, brownish, or white spots on the leaves and stems.



Figure 29. Broccoli Club Roots.
(Photo UMass Extension, 2010).



Figure 30. Root Rot and
Associated Discoloration of the
Leaves.



*Figure 31. Apple Scab Infection.
(Photo courtesy of Jack Kelly Clark, UCIPM 2000).*



Figure 32. Galls on a ear of corn caused by common smut. (Photo Courtesy of Jack Kelly Clark, UC IPM 2000).

Scabs (Fig. 31) appear corky and cracked on infected fruit.

Spots of yellow, orange, gray, brown, tan, purplish, red, or black on the plant parts are caused by several species of disease causing fungi like; Anthracnose, Alternaria, Fusarium, Cercospora, etc.

Smuts (Fig. 32) are the silver swellings or galls on leaves, flowers, tassels, and stems. They enlarge, darkened, and break open to expose the masses of black fungal spores.

Wilts are fungal damages wherein a plant's water conducting vessels are plugged causing the leaves to wilt, fall over and die.

Signs and symptoms of bacterial diseases:

Abnormal growths are outgrowths like galls or swellings of fast growing plant cells.

Soft rots (Fig. 33) are watersoaked soft spots or blights on leaves, stems, and fruits or the entire plant that lead to plant's death.

Wilts are bacterial damages wherein the plant's water-conducting vessels are plugged causing the leaves to wilt and die.

Symptoms of viral disease:

Leaf curl (Fig. 34) causes the leaf margin to roll either inward or upward and is rather stiff with yellowish margin. The leaves become thicker than normal, with leathery texture.

Mosaic (Fig. 35) causes the normal green color of leaves to become streaked with light green, yellow, yellow-orange, or white irregularly shaped patches. Often results in the yellowing of the plants. Mosaic viruses often cause economic losses in tomatoes and potatoes.



Figure 33. Bacterial Soft Rot in Potatoes. (Photo Courtesy of Gary D. Kleinschmidt, UC IPM, 2000)



Figure 34. Leaf Curl (Photo Courtesy of Jack Kelly Clark, UC IPM, 2000).



*Figure 35. Alfalfa Mosaic Virus
(Photo Courtesy of Jack Kelly Clark,
UC IPM, 2000)*



*Figure 36. Ring Spot with Concentric Rings
(Photo Courtesy of Jack Kelly Clark, UC IPM, 2000)*

Ring spot (Fig. 36) causes rings of pale or yellow spots on the leaves. With time, the spots begin to resemble a target with concentric rings.

Rosetting causes short and bushy growth. The leaves and the side branches grow in a crowded circles from a common center or crown, that they grow in a rosette (rose-like form).

Stunted growth causes the plant to be dwarfed and of inferior size and quality.

Symptoms of nematodes:

Stunted growth causes the plant to be dwarfed and of inferior size and quality.

Wilts are damages wherein the plants' water conducting vessels are plugged by the feeding of the nematode causing the leaves to wilt and die.

Abnormal growths. Roots may have many small, round nodules on them, and taproots, such as carrots, may develop many small side roots.

Appendix C. Prevention and Control of Disease by Pathogen.

Prevention and control of *fungus diseases*

1. Always make a plan to grow a healthy crop
2. Properly select plant cultivars that are fungal resistant and are common in your locality
3. Have proper plant spacing by following the recommended planting distances.
This enables light penetration and air flow
4. Have a healthy and well-balanced soil
5. Prune the overcrowded foliage
6. Pick and cut the infected plant parts
7. Uproot the heavily infected plants
8. Always practice proper field sanitation
9. Control the weeds
10. Practice crop rotation by alternating crops of non-related family groups during every cropping season
11. Spray your crops with safer and cheaper homemade plant extracts and other home-made solutions like any of the following;
Aloe, Basil, Coriander, Garlic, Ginger, Horsetail, Lemongrass, Malabar nut, Marigold, Mint, Neem, Onion Papaya, Pongam, Turmeric, Animal urine, Baking soda, Compost tea, Copper, Horticultural oil, Milk spray, Sulfur, Soap spray

Prevention and control of *bacteria disease*

1. Properly select your planting materials. Make sure that the seeds and transplants are seed certified or disease-free.
2. Select cultivars that are disease-resistant.
3. Have proper plant spacing by following the recommended planting distances.
This enables light penetration and air flow.
4. Prune infected parts immediately, once you see them. Disinfect pruning tools with bleach solution in between cuts. But remember to avoid working on wet plants.
5. Uproot the heavily infected plants. Properly dispose them.
6. Always practice proper field sanitation.
7. Control the weeds.
8. Spray your crops with safer and cheaper homemade plant extracts and other home-made solutions like any of the following;
Aloe, Horsetail, Malabar nut, Mint, Animal manure, Animal urine, Milk, Bleach, Copper, Horticultural oil, Sulfur.

Prevention and control of virus diseases

1. Control insect pests that are normally the carriers of viral disease; like aphids, leafhoppers, and whiteflies
2. Protect your seedlings with row covers to prevent them from early attack of the above-mentioned pests
3. Uproot the heavily infected plants
4. Always practice proper field sanitation
5. Control the weeds
6. Always remember not to work on your plants when they are wet

Prevention and control of diseases caused by Nematodes

1. Plant resistant varieties.
2. Keep the soil's organic matter level high to encourage nematode antagonists.
3. Tilling in a rye cover crop produces a substance toxic to nematodes.
4. Leaving fields fallow and weed-free for 1 to 2 years usually have an 80 to 90 percent per year reduction in root-knot populations.
5. In warmer areas, soil solarization (using the sun's heat to kill the seeds). Till soil, water thoroughly, and cover soil with sheets of clear 2– or 4–mil plastic. (A double layer, separated by a garden hose for instance, increases effectiveness.) Seal the edges with soil or stones. Sunlight passes through the plastic and heats the soil, which stays warm. The goal is to raise soil temperatures 3 to 6 inches deep above 100F. Depending upon the amount of sun and how hot it is, the process can take 6 to 8 weeks.

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